TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT:

CONSUMER POOL HEATERS

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the information presented in the final rule for consumer pool heaters.

1.2 STRUCTURE OF THE DOCUMENT

The TSD consists of 17 chapters and supporting appendices.

Chapter 1	Introduction: Describes the purpose of the TSD and outlines the structure of the document.
Chapter 2	Analytical Framework: Describes the general rulemaking process.
Chapter 3	Market and Technology Assessment: Characterizes the market for the considered products and the technologies available for increasing efficiency.
Chapter 4	Screening Analysis: Identifies all the design options that improve efficiency of the considered products, and determines which technology options are viable for consideration in the engineering analysis.
Chapter 5	Engineering Analysis: Describes the methods used for developing the relationship between increased efficiency and increased manufacturing cost and presents results of the analysis.
Chapter 6	Markups Analysis: Describes the methods used for establishing markups for converting manufacturing cost to consumer purchase price and presents results of the analysis.
Chapter 7	Energy Use Analysis: Describes the sources and methods used for generating energy-use estimates for the considered products as a function of potential standard levels and presents results of the analysis.
Chapter 8	Life-Cycle Cost and Payback Period Analysis: Describes the methods used for analyzing the economic effects of new or amended efficiency standards on individual consumers and users of the products with respect to LCC savings and PBP of higher efficiency products and presents results of the analysis.
Chapter 9	Shipments Analysis: Describes the methods used for forecasting shipments with and without new or amended efficiency standards and presents results of the analysis.

Chapter 10	National Impact Analysis: Describes the methods used for estimating the impacts of potential standards on national energy consumption and national economic benefit to consumers and presents results of the analysis.
Chapter 11	Consumer Subgroup Analysis: Describes the methods used for analyzing the effects of potential standards on different subgroups of consumers compared to all consumers and presents results of the analysis.
Chapter 12	Manufacturer Impact Analysis: Describes the methods used for analyzing the effects of potential standards on the finances and profitability of product manufacturers and presents results of the analysis.
Chapter 13	Emissions Impact Analysis: Describes the methods used for analyzing the impact of potential standards on national emissions of sulfur dioxide, nitrogen oxides, and mercury—as well as on carbon dioxide and other greenhouse gas emissions, and presents results of the analysis.
Chapter 14	Monetization of Emissions Reduction Benefits: Describes the methods used for estimating monetary benefits likely to result from reduced emissions expected to result from potential standards and presents results of the analysis.
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

Section 325(o)(2)(A) of the Energy Policy and Conservation Act (EPCA)[a], Public Law 94-163, 42 U.S.C. 6291 et seq. requires the U.S. Department of Energy (DOE) to establish energy conservation standards that achieve the maximum improvement in energy efficiency of consumer products that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A))[1] This chapter describes the general analytical framework that DOE uses in evaluating and developing such standards, and in particular, energy conservation standards for consumer pool heaters. The analytical framework is a description of the methodology, the analytical tools, and the relationships among the various analyses that are part of this analytical framework. The methodology that addresses the statutory requirement for economic justification, for example, includes analyses of life-cycle cost; economic impact on manufacturers and users; national benefits; effects, if any, on utility companies; and impacts from any lessening in competition among manufacturers.

The analyses performed as part of the final rule stage and reported in this technical support document (TSD) are listed below.

- A market and technology assessment to characterize the relevant product markets and existing technology options, including prototype designs.
- A screening analysis to review each technology option and determine if it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; would have adverse impacts on health and safety; or would utilize proprietary technology that represents a unique pathway to achieving a given efficiency level.
- An engineering analysis to develop cost-efficiency relationships that show the manufacturer's cost of achieving increased efficiency.
- An analysis of markups for determining product price; markups throughout the distribution channel relate the manufacturer production cost (MPC) to the retail price paid by the consumer.
- An energy and water use analysis to determine the annual energy and water use of the considered product for a representative set of users.
- A life-cycle cost (LCC) and payback period (PBP) analysis to calculate the savings in operating costs the consumer will realize throughout the life of the covered product compared to any increase in installed product cost likely to result directly from imposition of a standard.
- A shipments analysis to forecast product shipments, which then are used to calculate the national impacts of potential standards on energy consumption, net present value (NPV), and future manufacturer cash flows.
- A national impact analysis (NIA) to assess the aggregate impacts, at the national level, of potential energy conservation standards for the considered product, as

[a] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020), which reflect the last statutory amendments that impact Parts A and A-1 of EPCA.

measured by the NPV of total consumer economic impacts and the national energy savings (NES).
- A manufacturer impact analysis (MIA) to assess the potential impacts of energy conservation standards on manufacturers, such as impacts on capital conversion expenditures, marketing costs, shipments, and research and development costs.

2.2 ENERGY USE METRICS

Currently, manufacturers are required to demonstrate compliance with the energy conservation standards for pool heaters found at section 430.32(k) of Title 10 of the Code of Federal Regulations (CFR), which are based on the thermal efficiency metric. Thermal efficiency is a measurement of active mode efficiency, that is, when the pool heater is heating water. The current DOE test procedures for consumer pool heaters appear at 10 CFR part 430, subpart B, appendix P ("appendix P") and produce an integrated thermal efficiency metric which accounts for active, standby, and off mode energy use.[2] DOE's analysis of standards includes standby and off mode energy use estimates such that the standards being established by this final rule are in terms of the integrated thermal efficiency metric and in alignment with the latest test procedure.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterizes the relevant product markets and existing technology options, including working prototype designs, for the considered products.

2.3.1 Market Assessment

When analyzing potential energy conservation standards, DOE initially develops information that provides an overall picture of the market for the products analyzed, including the nature of the products, the industry structure, and market characteristics for the products. This activity consists of both quantitative and qualitative efforts based primarily on publicly available information. In the context of the final rule analysis, the subjects addressed in the market assessment for consumer pool heaters include manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE examined both large and small, foreign and domestic manufacturers. Finally, DOE reviewed other energy efficiency programs from utilities, individual States, and other organizations.

DOE reviewed relevant literature to develop an overall picture of the consumer pool heater industry in the United States. Industry publications, government agencies, and trade organizations provided the bulk of the information, including (1) major and minor manufacturers, (2) shipments estimates, and (3) industry trends. The analysis developed as part of the market and technology assessment is described in chapter 3 of this TSD.

2.3.2 Technology Assessment

DOE typically uses information relating to existing and past technology options and working prototype designs as inputs to determine what technologies manufacturers may use to attain higher performance levels. In consultation with interested parties, DOE developed a list of technologies for consideration. Initially, these technologies encompass all those that are technologically feasible. DOE developed its list of technologically feasible design options for consumer pool heaters through review of previous rulemaking data, product literature, trade publications and technical papers, discussions with manufacturers, and from direct examination during product testing and reverse engineering.

Chapter 3 of this TSD includes the detailed list of all technology options identified for potential efficiency improvements in consumer pool heaters.

2.4 SCREENING ANALYSIS

The screening analysis examines various technologies to determine whether they: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; (4) have adverse impacts on health and safety; or (5) would utilize proprietary technology that represents a unique pathway to achieving a given efficiency level. DOE developed an initial list of efficiency-enhancement options from the technologies identified as technologically feasible in the technology assessment. Then, DOE reviewed the list to assess each technology against the screening criteria listed above. Those technologies that were not screened out in the screening analysis were considered further in the engineering analysis. Chapter 4 of this TSD contains details on the screening analysis for consumer pool heaters.

2.5 ENGINEERING ANALYSIS

The engineering analysis establishes the relationship between efficiency and MPC. The purpose of the analysis is to estimate the incremental MPCs for a product that would result from increasing efficiency levels above the baseline model. This relationship serves as the basis for cost/benefit calculations applicable to individual consumers, manufacturers, and the Nation. Chapter 5 of this TSD discusses the product classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop the MPCs, the cost-efficiency curves, and the impact of efficiency improvements on the considered products.

The engineering analysis considered technologies not eliminated in the screening analysis. Technologies were designated as design options based on whether they were determined to be part of the most realistic design pathway to higher efficiency levels. DOE considered the analyzed design options in developing the cost-efficiency curves.

DOE typically uses one of two approaches to develop energy efficiency levels for the engineering analysis: (1) relying on observed efficiency levels in the market (*i.e.*, the efficiency-level approach), or (2) determining the incremental efficiency improvements associated with incorporating specific design options to a baseline model (*i.e.*, the design-option approach). Using the efficiency-level approach, the efficiency levels established for the analysis are determined based on the market distribution of existing products (in other words, based on the range of efficiencies and efficiency level "clusters" that already exist on the market). Using the design option approach, the efficiency levels established for the analysis are determined through detailed engineering calculations and/or computer simulations of the efficiency improvements from implementing specific design options that have been identified in the technology assessment. DOE may also rely on a combination of these two approaches. For example, the efficiency-level approach (based on actual products on the market) may be extended using the design option approach to interpolate to define "gap fill" levels (to bridge large gaps between other identified efficiency levels) and/or to extrapolate to the max-tech level (particularly in cases where the max-tech level exceeds the maximum efficiency level currently available on the market).

For this rulemaking, DOE used the efficiency-level approach, supplemented with the design-option approach for certain "gap fill" efficiency levels.

The efficiency levels that DOE considered in the engineering analysis are attainable using technologies currently available on the market in consumer pool heaters. DOE used the results of the testing and teardown analyses to determine a representative set of technologies and design strategies that manufacturers could use to achieve each higher efficiency level. This information provides interested parties with additional transparency of assumptions and results and the ability to perform independent analyses for verification. Chapter 5 of this TSD describes the methodology and results of the analysis used to derive the cost-efficiency relationships.

2.5.1 Baseline Efficiency Levels

For each established product class, DOE selected a baseline model as a reference point against which any changes resulting from energy conservation standards can be measured. The baseline model in each product class represents the characteristics of common or typical products in that class. Typically, a baseline model is one that exactly meets the current minimum energy conservation standards. DOE considered the standards for consumer pool heaters established in 10 CFR 430.32(k) as the baseline efficiency level for the gas-fired pool heater product class. However, energy conservation standards do not exist for the electric pool heater product class. In this case, the minimum efficiency available on the market is used as the baseline efficiency level.

2.5.2 Incremental Efficiency Levels

For the final rule analysis, DOE reviewed data in its Compliance Certification Database (CCD)[3] to evaluate the range of consumer gas-fired pool heater efficiencies currently available on the market. DOE also reviewed the Air-Conditioning, Heating and Refrigeration Institute's (AHRIs) Directory of the Certified Pool Heater Models[4] and manufacturer literature to evaluate the range of consumer electric pool heater efficiency currently available on the market. DOE used this data to identify clusters of models that correspond with higher efficiency levels. This information was used as the basis for defining the higher efficiency levels considered in the final rule analysis. DOE has determined that the analyzed efficiency level definitions are representative of the current market and provide measurable differences in terms of incremental efficiency and cost.

2.6 MARKUPS ANALYSIS

DOE analyzed product markups to convert the MPCs estimated in the engineering analysis to consumer prices, which then are used in analyzing the LCC and PBP and manufacturer impacts. To develop markups, DOE identified how consumer pool heaters are distributed from the manufacturer to the consumer. After identifying appropriate distribution channels, DOE relied on economic data from the U.S. Census Bureau, Securities and Exchange Commission (SEC) filings, and other sources to determine how prices are marked up as products pass from the manufacturer to the consumer. The manufacturer markup converts MPC to manufacturer selling price (MSP). DOE developed an average manufacturer markup by examining publicly available financial information, including SEC 10-K reports, and feedback from manufacturers.[5] Next, DOE developed baseline and incremental markups for each market player in the distribution channels using (1) 2017 U.S. Census *Annual Retail Trade Survey* (ARTS) for Miscellaneous Store Retailers,[6] (2) SEC 10-K reports for certain distributors and contractors from 2017-2021,[7] (3) 2017 U.S. *Economic Census* data for pool builder, pool contractor, and general and plumbing/mechanical contractors for commercial applications,[8,9,10,11] and (4) other miscellaneous sources.[12,13,14] Lastly, DOE applied state and local tax to derive the final consumer purchase prices for consumer pool heaters.[15]

Chapter 6 of this TSD provides details on DOE's development of markups for consumer pool heaters.

2.7 ENERGY USE ANALYSIS

To conduct the life-cycle cost (LCC) and payback period (PBP) analyses, DOE must determine the operating cost savings to consumers from using more efficient products. The goal of the energy use analysis is to determine the annual energy consumption of consumer pool heaters for use in the LCC, PBP, and NIA analysis. Different from current test procedure, which was developed in a laboratory setting, the analysis in chapter 7 seeks to estimate the distribution of annual energy consumption for pool heaters in the field, swimming pool and spa characteristics, and applications.

To establish a reasonable range of energy consumption in the field for consumer pool heaters, DOE first derived seven separate pool heater samples for each pool heater market type:

1) Pool heaters in single family homes that serve a swimming pool only,
2) Pool heaters in single family homes that serve both a swimming pool and spa,
3) Pool heaters in single family homes that serve a spa only,
4) Pool heaters in single-family community swimming pools or spas,
5) Pool heaters in multi-family community swimming pools or spas,
6) Pool heaters in indoor commercial swimming pools or spas, and
7) Pool heaters in outdoor commercial swimming pools or spas.

For pool heater market type 1,2, and 3, DOE primarily used data from the Energy Information Administration (EIA)'s 2015 Residential Energy Consumption Survey ("RECS 2015").[16] RECS is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units along with data on energy-related characteristics of the housing units and occupants. RECS 2015 collected data on 5686 housing units and was constructed by EIA to be a national representation of the household population in the United States. For market type 6, EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012)[17] records were used. As neither RECS 2015 nor CBECS 2012 have sufficient household or building information to distinguish market type 4, 5, and 7, DOE used a combination of sources including RECS 2015, CBECS 2012, 2009 and 2011 American Housing Survey,[18,19] and 2022 Pkdata[13] to determine the market share and sample for these sample subsets.

After deriving the sample weights for each sample subsets and determining burner operating hours, pool heating load, and pool operating hours for each samples home, DOE used a modified method to calculate annual energy consumption at considered efficiency levels for each household to account for actual field conditions. Therein, DOE took into account differences in operation between consumer pool heaters used in swimming pool compared to spas. DOE also took into account longer operating hours for heat pump pool heaters (HPPH) compared to gas-fired pool heaters (GPH) and electric resistance pool heaters (ERPHs), because of lower output capacity and decreased output capacity during colder months.

Chapter 7 of this TSD provides more detail about DOE's approach to characterizing energy use of consumer pool heaters.

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

In determining whether an energy conservation standard is economically justified, DOE considers the economic impacts of efficiency levels on consumers. Energy conservation standards produce a change in consumer operating costs—usually a decrease—and a change in product purchase price—usually an increase. DOE used the following two metrics to measure potential impacts on consumers.

- LCC is the total consumer cost of an appliance or product, generally over the life of the product. The LCC calculation includes total installed cost (product MSP, markups throughout distribution channel, sales tax, and any installation costs); operating costs (energy, repair, and maintenance costs); product lifetime, and discount rate. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- PBP measures the amount of time required for consumers to recover the assumed higher purchase price of a more energy efficient product through reduced operating costs. Inputs to the calculation of PBP include the installed cost to the consumer and first-year operating costs. DOE's analysis produces a simple PBP based on using single-point average values to estimate the purchase price and undiscounted first-year operating cost.

The LCC and simple PBP analysis utilized values that reflect unit energy consumption in the field. For electricity prices, DOE used marginal and average prices which vary by season, region, and baseline electricity consumption level for the LCC. DOE first derived base year

(2021) average annual residential and commercial electricity, natural gas, and LPG prices for each State using the most recent historical data from EIA. DOE then developed monthly energy price factors for each energy source based on long-term price data from the same sources. Monthly electricity and natural gas prices were adjusted using seasonal marginal price factors to determine monthly marginal electricity and natural gas prices. To estimate energy prices in future years, DOE multiplied the 2021 energy prices by the forecast of annual average price changes for each of the nine census divisions from EIA's Reference case in the Annual Energy Outlook 2022 (AEO 2022).[20] For each consumer sampled, DOE applied the projection for the census division in which the consumer was located. To estimate the trends after 2050, DOE used the average rate of change during 2045–2050 to project the electricity price for years after 2050. The average price is applied to the energy use in the no-new-standards case, while the marginal price is applied to the energy savings when comparing each efficiency level to the no-new-standards case.

As described in section 2.7, DOE developed samples that use consumer pool heaters. By developing such samples, DOE was able to calculate the LCC to account for the variability in energy consumption and electricity price among users of pool heaters.

DOE used probability distributions to characterize discount rates and product lifetimes. DOE developed discount rates for consumers that purchase pool heaters from estimates of the interest rate, or finance cost, applied to purchases of consumer products. The stream of savings was discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE derived the discount rates for companies or public entities that purchase pool heaters by estimating the cost of capital. As discount rates can differ across industries, DOE estimated separate discount rate distributions for a number of aggregate sectors with which elements of the LCC building sample can be associated.

To estimate the percentage of consumers who would be affected by a standard at each efficiency level, DOE first projected no-new-standards case efficiency distribution in 2022 for pool heaters, using inputs from manufacturer interviews, stakeholder comments, and data about the availability of consumer pool heater models by efficiency in 2022 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance for heat pump pool heaters,[4] DOE's 2022 CCD for gas-fired pool heaters,[3] and CEC's 2022 MAEDbS for heat pump and gas-fired pool heaters models,[21] and manufacturer product literature. To extrapolate from 2022 to 2028, DOE assumed different growth rates for the electric resistance and heat pump pool heater shipments. These assumptions resulted in a 7.8 percent overall market share for electric resistance pool heaters in 2028 and 4.9 percent overall market share for gas-fired pool heaters with standing pilot. Using the projected distribution of efficiencies for consumer pool heaters, DOE randomly assigned a product efficiency to each household and commercial user drawn from the consumer samples. If a consumer is assigned a product efficiency that is greater than or equal to the efficiency under consideration, the consumer would not be affected by a standard at that efficiency level.

DOE used Monte Carlo simulations and probability distributions to model both the uncertainty and variability in inputs to the LCC and PBP analysis. DOE developed LCC and PBP spreadsheet models that incorporate the results of Monte Carlo simulations sampling from probability distributions. Because certain key inputs to the analysis consist of probability distributions rather than single-point values, the analysis produces a range of LCC and PBP results that enabled DOE to identify the percentage of consumers who will achieve LCC savings or incur net cost at each considered efficiency level.

In performing an iteration of the Monte Carlo simulation for a given consumer, product efficiency is chosen based on its probability. If the chosen product efficiency is greater than or equal to the efficiency level under consideration, the LCC and PBP calculation reveals that a consumer is not affected by the efficiency level. By accounting for consumers who already purchase more efficient products, DOE avoided overstating the potential benefits from increasing product efficiency.

Chapter 8 of this TSD describes the results of the LCC and PBP analysis.

2.9 SHIPMENTS ANALYSIS

DOE needs projections of product shipments to calculate national energy savings (NES) and net present value (NPV), as well as to the manufacturer impact analysis (MIA). DOE developed the shipment model for consumer pool heaters, especially EPHs and GPHs, and disaggregated the shipment into two market sectors: residential sector and commercial sector. The consumer pool heater shipments model considered three product market segments:

- *Existing owners of a swimming pool, spa, or hot tub with consumer pool heaters (replacement shipments)*: These were defined as existing swimming pools with consumer pool heaters installed.
- *New swimming pools, spa, or hot tub with consumer pool heaters (shipments to new swimming pools, spas or hot tubs)*: This fraction was defined as the new swimming pool, spa, or hot tub saturation, which varies by year, market sector, and by product class.
- *New owners (shipments to new owners)*: These were defined as existing swimming pools, spas, or hot tubs that acquire consumer pool heaters for the first time during the analysis period. The new owners also included product switching for swimming pools, spas, or hot tub owners that previously had a consumer pool heater and switch to a new consumer pool heater of a different fuel type (electric or gas-fired).

The model starts from a historical base year and calculates retirements and shipments by market segment for each year of the analysis period. This approach produces an estimate of the total product stock, broken down by age or vintage, in each year of the analysis period. In addition, the product stock efficiency distribution is calculated for the case without new or amended standards ("no-new-standards case") and for each standards case for each product class. The stock distribution is used in the national impact analysis (NIA) to estimate the total costs and benefits associated with each efficiency level.

To project shipments of replacement units in no-new-standards case, DOE utilized the 11 year estimated lifetime to develop a survival function for pool heaters. DOE applied survival function to the existing stock of products. DOE also took into account non-replacement rate of retired (failed) residential consumer pool heaters. For replacements in new standard cases, as consumer decisions to purchase or repair a pool heater are influenced by the purchase price and operating cost of the product, they may be different under standards cases at different efficiency levels (ELs). These decisions were modeled by estimating the purchase price elasticity for pool heaters. This elasticity, along with information obtained from the life-cycle cost (LCC) and payback period (PBP) analysis on the change in purchase price and operating costs at different ELs, are used in the shipments model to estimate the change in shipments under potential standards at different ELs.

To project shipments in new swimming pools and spas, DOE multiplied forecasted new swimming pools and spas by forecasted consumer pool heater saturations from 2028-2057.

To estimate shipments to new owners, DOE multiplied the stock of swimming pool and spa owners that do not currently have a pool heater by the new pool owner factor. The swimming pool and spa stock is calculated by shipments model using new swimming pool and spa installations and assuming very low demolition rates of existing pools and spas. DOE did not consider the potential impact of consumers opting to switch from an electric pool heater to a gas-fired pool heater or from gas-fired pool heaters to electric pool heaters in response to the evaluated standards.

See chapter 9 of this TSD for more details regarding the shipments analysis.

2.10 NATIONAL IMPACT ANALYSIS

DOE developed NIA for electric pool heaters (EPHs) and gas-fired pool heaters (GPHs). For each potential standard level, DOE evaluated the following impacts: (1) national energy savings (NES), (2) monetary value of the energy savings for consumers of pool heaters,[b] (3) increased total installed costs, and (4) the net present value (NPV), which is the difference between the savings in operating costs and the increase in total installed costs. DOE determined both the NPV and NES for all the trial standard levels (TSLs) examined for consumer pool heaters. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet model to forecast NES and the national consumer economic costs and savings resulting from potential efficiency levels.

A key component of DOE's NIA is the energy efficiency projected over time for the no-new-standards case and for each candidate standard level. DOE assumed a "roll-up" scenario to establish the efficiency distribution under different candidate standard levels. Product efficiencies in the no-new-standards case that do not meet the standard under consideration would "roll up" to meet the new standard level. All efficiency in the no-new-standards case that were above the standard under consideration would not be affected.

[b] For pool heaters installed in commercial applications, the consumer is the business or other entity that pays for the equipment (directly or indirectly) and its energy costs.

2.10.1 National Energy Savings

DOE calculated the NES associated with the difference between the no-new-standards case and each standards case for EPHs and GPHs. DOE's analysis considered products shipped in the 30-year period beginning in the compliance year—in this case, 2028. DOE calculated cumulative energy savings throughout the analysis period, which ends when all of the products shipped in 2057 are retired from the stock.

The inputs for determining the NES were: (1) annual energy consumption per unit, (2) shipments and product stock, (3) conversion factors for site-to-primary, (4) full-fuel-cycle (FFC), and (5) rebound effect factor.

DOE calculated the national annual energy consumption for each energy measurement type by multiplying the national annual site energy consumption (*i.e.*, the energy consumed at the household or establishment) for each energy source type by the conversion factor for each energy measurement type. DOE estimated energy consumption and savings based on site energy consumption, which it then converted to primary and FFC energy using annual conversion factors derived from the most recent version of the National Energy Modelling System (NEMS). DOE calculated annual NES for each energy measures and for a given year as the difference between the national annual energy consumption projections: the no-new-standards case scenario and each standards case scenario. Cumulative energy savings are the sum of the NES for each year throughout the forecast period. DOE also accounted for the direct rebound effect for residential applications when estimating the NES from potential standards.

2.10.2 Net Present Value of Consumer Benefits

DOE calculated the NPV of consumer benefits associated with the difference between the no-new-standards case and each standards case for EPHs and GPHs. The inputs for determining the NPV of the total costs and benefits experienced by consumers were (1) total installed cost per unit, (2) annual operating costs savings per unit, (3) shipments and product stock, (4) discount factor, and (5) rebound effect factor to calculate the present value of costs and savings.

DOE calculated the total annual consumer savings in operating costs by multiplying the number or stock of the product by its per-unit operating cost savings. DOE calculated the total annual increases in consumer product price by multiplying the number or shipments of the product by its per-unit increase in consumer cost. DOE determined the present value of operating cost savings and total increased product cost for each year from 2028 to 2057. This method accounted for the year-to-year differences in annual operating cost savings.

DOE calculated installed cost and operating cost savings as the difference between a standards case and a no-new-standards case. As with the calculation of NES, DOE did not use no-new-standards case shipments to calculate total annual installed costs and operating cost savings. To avoid including savings attributable to shipments displaced by consumers deciding not to buy higher-cost products, DOE used the standards-case projection of shipments and, in turn, the standards-case stock, to calculate these quantities.

DOE also applied a discount factor which was developed from the national discount rate and the number of years between the "present" (year to which the sum is being discounted) and the year in which the costs and savings occur, in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on developing regulatory.[22] DOE defined the present year as 2028.

Chapter 10 of this TSD provides additional details regarding the NIA.

2.11 CONSUMER SUBGROUP ANALYSIS

DOE has identified consumer subgroups that may be affected disproportionately by new or revised energy conservation standards – senior-only households and small business. The purpose of a subgroup analysis is to determine the extent of any such disproportional impacts.

DOE analyzed the life-cycle cost (LCC) impacts and payback period (PBP) for those consumers from the considered energy efficiency levels. DOE evaluated the impacts of the considered energy efficiency levels for pool heaters on households occupied solely by senior citizens (*i.e.*, senior-only households) and consumer pool heaters installed by small businesses. DOE did not evaluate low-income consumer subgroup because the sample size of the subgroups is too small for meaningful analysis. The analysis used subsets of the consumer pool heater sample composed of households or buildings that meet the criteria for the subgroup.

2.12 MANUFACTURER IMPACT ANALYSIS

The purpose of the MIA is to identify the likely impacts of potential new and/or amended energy conservation standards on manufacturers. In the MIA, DOE assesses industry and subgroup cash flows and industry net present value (INPV). DOE also assesses impacts on competition, manufacturing capacity, employment, and cumulative regulatory burden (CRB). The Process Rule[c] provides guidance for conducting this analysis with input from manufacturers and other interested parties.

As part of the final rule analysis, DOE collects, evaluates and reports industry information. Chapter 12 of this TSD provides details on the MIA methodology and the MIA findings.

2.13 EMISSIONS ANALYSIS

In the emissions analysis, DOE estimated the reduction in power sector combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), mercury (Hg), methane (CH_4) and nitrous oxide (N_2O) from potential energy conservation standards for the considered products, as well as emissions at the building site if applicable. In addition, DOE estimated emissions impacts in production activities (extracting, processing, and transporting

[c] On February 14, 2020 the Department of Energy published a Process Rule clarify the procedures used to evaluate the economic justification of new or amended energy conservation standards. 85 FR 8626

fuels) that provide the energy inputs to power plants and for site combustion. These are referred to as "upstream" emissions. Together, these emissions account for the full-fuel-cycle (FFC). In accordance with DOE's FFC Statement of Policy (76 FR 51282 (August 18, 2011), as amended at 77 FR 49701 (Aug. 17, 2012)), the FFC analysis included impacts on emissions of methane and nitrous oxide, both of which are recognized as greenhouse gases. For more detail on the Emissions Analysis, see chapter 13 of the final rule TSD.

2.14 EMISSIONS MONETIZATION

As part of the development of this adopted rule, for the purpose of complying with the requirements of Executive Order 12866, DOE considered the estimated monetary benefits from the reduced emissions of NO_X and SO_2 that are expected to result from each of the TSLs considered. In order to make this calculation analogous to the calculation of the NPV of consumer benefit, DOE considered the reduced emissions expected to result over the lifetime of products shipped in the projection period for each TSL. Further detail on the monetization of emissions analysis is provided in chapter 14 and appendix 14A of this TSD.

2.15 UTILITY IMPACT ANALYSIS

The utility impact analysis estimates several effects on the electric power generation industry that would result from the adoption of new or amended energy conservation standards. The utility impact analysis estimates the changes in installed electrical capacity and generation that would result for each TSL. The analysis is based on published output from the National Energy Modeling System (NEMS) associated with *AEO2022*. NEMS produces the *AEO* Reference case, as well as a number of side cases that estimate the economy-wide impacts of changes to energy supply and demand. For the current analysis, impacts are quantified by comparing the levels of electricity sector generation, installed capacity, fuel consumption and emissions in the *AEO2022* Reference case and various side cases.

Details of the methodology are provided in the appendices to chapters 13 and 15 of this TSD.

2.16 EMPLOYMENT IMPACT ANALYSIS

Energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products. DOE evaluated direct employment impacts in the MIA. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

Indirect employment impacts were investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model.[d] The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies in buildings, industry, and transportation. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments. Further detail is provided in chapter 16 of this TSD.

2.17 REGULATORY IMPACT ANALYSIS

DOE prepared a regulatory impact analysis (RIA). DOE identified major alternatives to standards that represent feasible policy options to reduce the energy consumption of pool heaters. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each alternative to the effectiveness of the adopted standard. DOE recognized that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE based its assessment on the recorded impacts of any such initiatives to date, but also considered information presented by interested parties regarding the impacts current initiatives may have in the future. Further detail on the RIA is provided in chapter 17 of this TSD.

[d] M.J. Scott, O.V. Livingston, P.J. Balducci, J.M. Roop, and R.W. Schultz, *ImSET 3.1: Impact of Sector Energy Technologies: Model Description and User's Guide*, PNNL-18412, Pacific Northwest National Laboratory (2009) (Available at: www.pnl.gov/main/publications/external/technical_reports/PNNL-18412.pdf).

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

3.1 INTRODUCTION

This chapter provides a profile of the consumer pool heater industry in the United States. The U.S. Department of Energy (DOE) developed the market and technology assessment presented in this chapter primarily from publicly available information. This assessment is helpful in identifying the major manufacturers and their product characteristics, which form the basis for the engineering and the life-cycle cost (LCC) analyses. Present and past industry structure and industry financial information help DOE in the process of conducting the manufacturer impact analysis.

This chapter consists of the market assessment and the technology assessment. The goal of the market assessment is to develop a qualitative and quantitative characterization of the pool heater industry and market structures based on publicly available information and data, and from information that obtained directly from manufacturers and other interested parties. DOE examined publicly available information and data from various sources, including DOE's Compliance Certification Database[a] (CCD), the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance[b] ("AHRI Directory"), the California Energy Commission (CEC) Modernized Appliance Efficiency Database System[c] (MAEDbS; "CEC Database"), and manufacturer product literature. The market assessment addresses manufacturers and their market shares, existing regulatory and non-regulatory efficiency improvement initiatives, product classes, product characteristics and performance, and trends in product markets. DOE performs the technology assessment to develop a preliminary list of technologies (referred to as technology options) that could be used to improve the efficiency of consumer pool heaters.

3.2 DEFINITIONS

"Pool heater" is defined in The Energy Policy and Conservation Act of 1975 (EPCA; 42 U.S.C. 6291 et seq.), as amended, and in title 10 of the Code of Federal Regulations (CFR) part 430.2 as an appliance designed for heating nonpotable water contained at atmospheric pressure, including heating water in swimming pools, spas, hot tubs and similar applications." (42 U.S.C. 6291 (25); 10 CFR 430.2)

In addition, DOE has defined "electric resistance" pool heaters and "electric heat pump pool heater" in 10 CFR part 430, subpart B, appendix P ("appendix P") as follow:

Electric resistance pool heater means an appliance designed for heating nonpotable water and employing electric resistance heating elements.

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[a] DOE. *Compliance Certification Management System*. Available at https://www.regulations.doe.gov/certification-data/ (last accessed Oct. 10, 2022).
[b] AHRI. *Directory of Certified Heat Pump Pool Heater Models*. Available at https://www.ahridirectory.org (last accessed Oct. 10, 2022).
[c] CEC. *Modernized Appliance Efficiency Database System*. Available at https://cacertappliances.energy.ca.gov/Pages/Search/AdvancedSearch.aspx (last accessed Oct. 10, 2022).

Electric heat pump pool heater means an appliance designed for heating nonpotable water and employing a compressor, water cooled condenser, and outdoor air coil.

DOE used the definitions below for electric pool heaters, electric spa heaters, gas-fired pool heaters, oil-fired pool heaters, and portable electric spa in its analysis to determine whether to amend energy conservation standards and has determined to add these definitions to 10 CFR 430.2.

Electric pool heater means a pool heater other than an electric spa heater that uses electricity as its primary energy source.

Electric spa heater means a pool heater that (1) uses electricity as its primary energy source; (2) has an output capacity (as measured according to appendix P to subpart B of §430) of 11 kW or less; and (3) is designed to be installed within a portable electric spa.

Gas-fired pool heater means a pool heater that uses gas as its primary energy source.

Oil-fired pool heater means a pool heater that uses oil as its primary energy source.

Portable electric spa means a self-contained, factory-built spa or hot tub in which all control, water heating and water circulating equipment is an integral part of the product. Self-contained spas may be permanently wired or cord connected.

3.3 PRODUCT CLASSES

When evaluating and establishing energy conservation standards, DOE divides covered products into product classes by the type of energy used, by capacity, or other performance-related features that justify differing standards. In making a determination whether a performance-related feature justifies a different standard, DOE must consider such factors as the utility of the feature to the consumer and other factors DOE determines are appropriate. (42 U.S.C. 6295(q))

DOE has determined to differentiate between electric pool heaters and electric spa heaters on the basis that they provide different utility to the consumer. DOE understands that electric spa heaters are often incorporated into the construction of a spa or hot tub. Therefore, DOE will consider electric spa heaters as a separate product class from electric pool heaters. As discussed in chapter 5 of this TSD, DOE did not perform energy conservation standards analysis for electric spa heaters as there are no identified technology options that could be implemented to improve the integrated thermal efficiency of these products.

Table 3.3.1 describes which product classes are examined in this rulemaking, and indicates those in which DOE considered for standards analysis in this final rule.

Table 3.3.1 Final Rule Analysis Consumer Pool Heater Product Classes

Fuel Type	Product Class	Additional Description of Product Class	Analyzed in Final Rule Analysis?
Electric	Electric Pool Heater	-	Yes
	Electric Spa Heater	Output Capacity ≤ 11 kW; Installed within a portable electric spa	No
Gas	Gas-Fired Pool Heater	-	Yes
Oil	Oil-Fired Pool Heater	-	No

3.4 PRODUCT TEST PROCEDURES

DOE published a final rule regarding its direct heating equipment (DHE) and pool heater test procedures on January 6, 2015 ("January 2015 final rule") adopting provisions for testing electric resistance and electric heat pump pool heaters. 80 FR 792. DOE's test procedure for consumer pool heaters is found at 10 CFR 430.23(p) and appendix P.

The January 2015 final rule incorporated by reference the following industry standards: AHRI Standard 1160-2009, "Performance Rating of Heat Pump Pool Heaters" ("AHRI 1160-2009"), and American National Standards Institute (ANSI)/American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 146-2011, "Method of Testing and Rating Pool Heaters" ("ASHRAE 146-2011"), to establish testing procedures for electric resistance and electric heat pump pool heaters. The ASHRAE 146-2011 industry standard provides a method by which to calculate the thermal efficiency (E_t) of electric resistance pool heaters as well as heat pump pool heaters, where the coefficient of performance (COP) is expressed as thermal efficiency. AHRI 1160-2009 specifies the ambient conditions at which to test a heat pump pool heater. Appendix P also references ANSI Z21.56-2006 which was the industry standard test method for gas-fired pool heaters and produces a thermal efficiency value. At the time of this analysis, AHRI 1160-2009, ASHRAE 146-2011, and ANSI Z21.56-2006 are still referenced in appendix P but they have been amended by AHRI 1160-2014 with Addendum 1 ("AHRI 1160-2014A"), ASHRAE 146-2020, and ANSI Z21.56-2017, respectively.

EISA 2007 amended EPCA to require DOE to amend its test procedures for all covered products to include measurement of standby mode and off mode energy consumption. (42 U.S.C. 6295(gg)(2)(A)) To satisfy this provision, the January 2015 final rule adopted a method by which to calculate the integrated thermal efficiency which incorporates the active mode thermal efficiency along with the standby and off mode energy consumption. DOE is using the integrated thermal efficiency metric in the determination of the potential establishment of energy conservation standards as defined by the DOE test procedure found at 10 CFR 430.23(p).

The January 2015 final rule required manufacturers to utilize the new test procedure (including the integrated thermal efficiency metric, TE_I) for any representations of efficiency for pool heaters starting July 6, 2015. However, the certification requirements for consumer pool heaters at 10 CFR 429.24 were not updated in the January 2015 final rule and had not been updated at the time of this analysis. Therefore, in the gathering of information for the analysis, DOE was limited to the COP metrics provided by some manufacturers in the case of electric pool heaters, and thermal efficiency in the case of gas-fired pool heaters.

Since the COP and thermal efficiency metrics only capture active mode energy consumption (*i.e.,* does not incorporate standby and off mode energy consumption), DOE used the test procedure calculations in appendix P to convert from the existing COP values (at the "High Air Temperature –Mid Humidity" rating conditions) in the case of electric pool heaters, or thermal efficiency in the case of gas-fired pool heaters to ratings under the new integrated thermal efficiency metric (which includes standby and off mode energy consumption). DOE calculated the integrated thermal efficiency metric by combining the rated COP or thermal efficiency of the product with a 'typical-case' standby and off mode electricity draw, since manufacturers do not advertise the standby and off mode electricity use of their products.

DOE determined the 'typical case' standby and off mode electricity consumption through testing of multiple products in each product class, after which manufacturers were invited to comment on whether the value was representative of pool heaters during confidential manufacturer interviews. The typical case standby used in the analysis are described in greater detail in chapter 5 of the final rule TSD.

3.5 MANUFACTURER INFORMATION

The following market assessment identifies the manufacturer trade associations; domestic and international manufacturers of consumer pool heaters, and their corresponding market shares; and regulatory and non-regulatory programs. The market assessment also provides historical shipment data; describes the cost structure for the consumer pool heater industry; and summarizes relevant market performance data for consumer pool heaters.

3.5.1 Trade Associations

DOE recognizes the importance of trade groups in disseminating information and providing growth to the industry they support. To gain insight into the consumer pool heater industry, DOE researched various associations available to manufacturers, suppliers, and users of such products. DOE also used the member lists of these groups to construct a database of domestic manufacturers.

DOE identified two trade groups that support or have an interest in the pool heater industry. These two trade groups were AHRI and the Pool & Hot Tub Alliance (PHTA).

3.5.1.1 Air-Conditioning, Heating, and Refrigeration Institute

AHRI is a national trade association representing manufacturers of air conditioning, heating, ventilation and commercial refrigeration equipment and components. AHRI was established in January of 2008, when the Air-Conditioning and Refrigeration Institute (ARI) merged with the Gas Appliance Manufacturers Association (GAMA). AHRI's scope includes gas-fired, oil-fired, and electric products and equipment.

According to its website, AHRI describes itself as a "North American association with global interests and services, serving its membership of 300-plus HVACR and water heating equipment manufacturers through operations in the United States, Canada, China, Dubai, India, and Mexico. AHRI members manufacture quality, efficient, and innovative HVACR equipment and components for sale around the world. These products account for more than 90 percent of the residential and commercial equipment manufactured and sold in North America." Additionally, AHRI states that it "advocates on behalf of its members at all levels of the United States government and ensures that members' interests are included in final drafts of legislation." AHRI also develops industry-recognized performance standards for industry equipment.[1] AHRI maintains the AHRI Product Performance Certification Program. AHRI also maintains a database of products and equipment tested under its certification program on its website. This database is known as the AHRI Directory[2], and the majority of heat pump pool heaters currently manufactured by member manufacturers are included in this database.

3.5.1.2 Pool & Hot Tub Alliance

PHTA[3] "is the world's oldest and largest association representing swimming pool, spa, and hot tub manufacturers, manufacturers' agents, builders, designers, distributors, suppliers, installers, retailers, and service technicians. For more than half a century, PHTA has been serving members and the public with critical industry knowledge that ranges from sound regulatory practice to industry trends and consumer attitudes. Since 1983, PHTA is the only industry organization accredited by the American National Standards Institute as the recognized Standards Development Organization to promote and develop the nation's standards for swimming pools and hot tubs." On April 1, 2019 the National Swimming Pool Foundation and the Association of Pool & Spa Professionals ("APSP") unified to form PHTA.

3.5.2 Manufacturer Information

The following section provides information about manufacturers of electric and gas-fired pool heaters, including potential small business impacts.

3.5.2.1 Manufacturers and Market Shares

DOE identified 18 manufacturers of electric pool heaters. Table 3.5.1 lists these manufacturers. Since the publication of the April 2022 NOPR, Intermatic Incorporated acquired AquaPro System, LLC.[4]

Table 3.5.1 All Electric Pool Heater Manufacturers

Heat Pump	Electric Resistance*	Both Heat Pump and Electric Resistance
AquaComfort Solutions, LLC	Coates Heater Company, Inc	Paloma Co. Ltd
Calorex USA LLC (AquaTherm Heat Pumps)	Consolidated Pool and Spa Industries Inc.	
Fairland Group Limited		
Fluidra, SA		
G&F Manufacturing		
Guangdong Phnix Eco-Energy Solution Ltd.		
Hayward Industries, Inc.		
Intermatic Incorporated (AquaPro Systems)		
Nirvana Chauffe Piscine Inc		
Pentair Public Limited Company		
Sima Pools and Spas		
Team Horner Group, Inc		
Thermeau Industries Inc.		
Titan Systems		
United States ThermoAmp, Inc.		

*Electric spa heaters are not listed as they are excluded from the definition of electric pool heater.

Due to the small total size of the electric pool heater market and confidentiality concerns, DOE is unable to disclose any market share data for electric pool heater product manufacturers. In Table 3.5.2 manufacturers are divided into "major" and "other" based on the current industry characteristics, DOE research, and discussions with manufacturers. DOE estimates that "major" companies have larger market shares than those designated as "other" manufacturers.

Table 3.5.2 Electric Pool Heater Manufacturers Categorization

Major Manufacturers	Other Manufacturers
Hayward Industries, Inc.	AquaComfort Solutions, LLC
Paloma Co., Ltd	Calorex USA LLC (AquaTherm Heat Pumps)
Pentair Public Limited Company	Coates Heater Company, Inc.
Team Horner Group	Consolidated Pool and Spa Industries
Fluidra, SA	Fairland Group Limited
	G&F Manufacturing
	Guangdong Phnix Eco-Energy Solution Ltd.
	Intermatic Incorporated (AquaPro Systems)
	Nirvana Chauffe Piscine Inc
	Sima Pools and Spas
	Thermeau Industries, Inc.
	Titan Systems
	United States ThermoAmp, Inc.

DOE identified six gas-fired pool heater manufacturers. In Table 3.5.3 DOE similarly divided gas-fired pool heater manufacturers into “major” and “other” based on the current industry characteristics, DOE research, and discussions with manufacturers. Major companies have larger market shares.

Table 3.5.3 Gas-Fired Pool Heater Manufacturers Categorization

Major Manufacturers	Other Manufacturers
Fluidra, SA	A. O. Smith Corporation (Lochinvar)
Hayward Industries, Inc.	Bradford White Company (Laars Heating System Company)
Paloma Co., Ltd.	
Pentair Water Pool and Spa Inc.	

3.5.2.2 Small Business Impacts

DOE realizes that small businesses may be disproportionately affected by the promulgation of energy conservation standards for electric pool heaters. The Small Business Administration (SBA) defines small business manufacturing enterprises for pool heaters as those having 500 employees or fewer.[5] SBA lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry establishes the largest size that a for-profit entity can be while still qualifying as a small business for Federal Government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. Pool heating manufacturing is classified under NAICS 333414, “Heating Equipment (except warm air furnaces) Manufacturing.” The size standard is 500 employees or fewer.

DOE studied the potential impacts on these small businesses as a part of the manufacturer impact analysis (chapter 12). Table 3.5.4 lists the small business pool heating manufacturers that DOE identified for electric pool heaters. DOE did not identify any small businesses which manufacture gas-fired pool heaters.

Table 3.5.4 Small Business Manufacturers of Electric Pool Heaters

Electric Pool Heaters
AquaComfort Technologies, LLC
Calorex USA LLC (AquaTherm)
Coates Heater Company
G&F Manufacturing
Team Horner Group
United States ThermoAmp, Inc.

3.5.3 Market Performance Data

DOE combined information from the CCD, AHRI Directory, and CEC Database with other publicly available data from manufacturers’ catalogs of pool heaters to develop a combined database and an understanding of the pool heater market.

3.5.3.1 Electric Pool Heater

The output capacity and COP of a heat pump, which utilizes ambient air as a heat source, are dependent upon the air temperature, air humidity, and pool water temperature at which the COP is determined. Therefore, the measured COP depends upon the rating conditions at which the products were tested. Typically, manufactures test their heat pump pool heaters under one or all of the testing conditions outlined in AHRI 1160-2014. These rating conditions are typically described as “High Air Temperature-High Humidity”, “High Air Temperature-Mid Humidity”, and “Low Air Temperature-Mid Humidity” conditions. In AHRI 1160-2009, the High Air Temperature-High Humidity rating condition is not outlined but the other two are the same as in AHRI 1160-2014. The relative humidity, dry bulb air temperatures, and wet bulb air temperatures for each rating condition from AHRI 1160-2014 are outlined in Table 3.5.5. For all three rating conditions the water entering the unit must be at 80 °F. AHRI 1160-2009 specifies a flow rate of 0.450 gpm per 1000 Btu/h or less if specified by the manufacturer, but no less than 30 gpm.

Table 3.5.5 Typical Rating Conditions for Electric Heat Pump Pool Heaters

Rating Condition	Relative Humidity (%)	Dry Bulb Air Temperature (°F)	Wet Bulb Air Temperature (°F)	Inlet Water Temperature (°F)
High Air Temperature-High Humidity	80	80.6	75.8	80
High Air Temperature-Mid Humidity	63	80.6	71.2	80
Low Air Temperature-Mid Humidity	63	50.0	44.3	80

DOE’s combined database contains information such as manufacturer name, model number, and COP at various rating conditions. The “High Air Temperature-Mid Humidity” condition is the testing condition used in the DOE test procedure.

As stated in section 3.4, the DOE test procedure measures both active mode and standby and off mode energy consumption in the determination of integrated thermal efficiency. Therefore, DOE converted the COP at the “High Air Temperature-Mid Humidity” condition into integrated thermal efficiency by accounting for the additional electricity use in standby and off mode and using the calculation methods in appendix P.

Figure 3.5.1 shows the distribution of output capacity at the “High Air Temperature-Mid Humidity” rating condition for electric heat pump pool heaters in the database. Figure 3.5.2 shows the distribution of electric heat pump pool heater models in the database when COP is converted into integrated thermal efficiency as described in section 3.4. Note that Figure 3.5.2 does not include electric resistance pool heaters. There are 78 individual models of electric resistance pool heaters, all of which have an integrated thermal efficiency of between 98 and 99 percent. DOE additionally investigated the efficiency range of heat pump pool heaters with cooling modes and verified that these products exist at similar efficiencies as products without cooling modes.

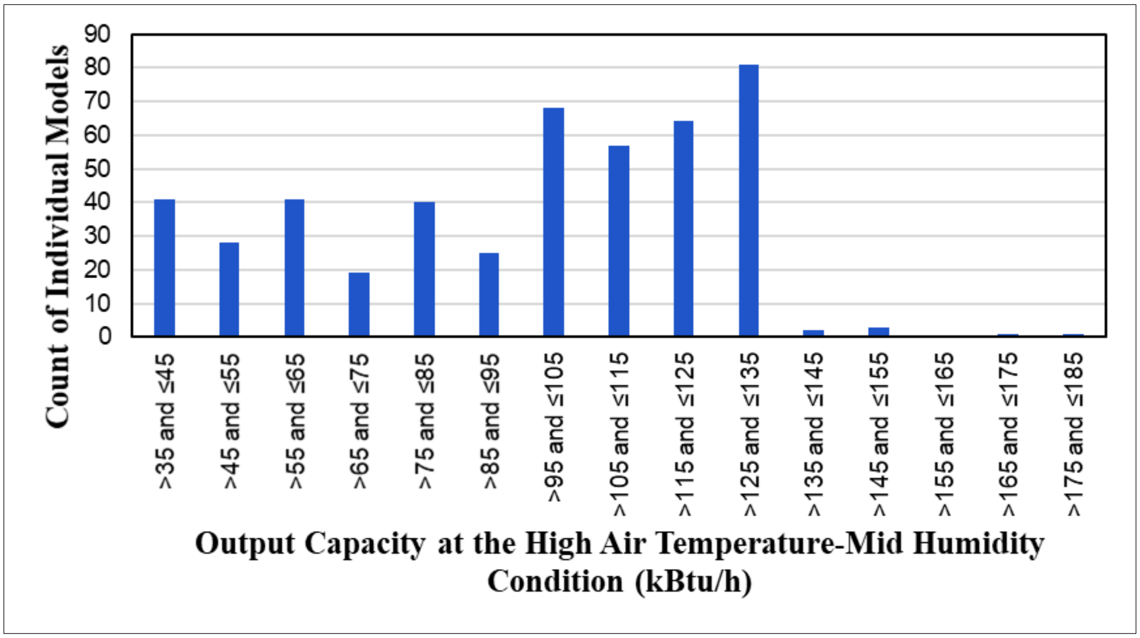


Figure 3.5.1 Distribution of Electric Heat Pump Pool Heater Individual Models by Output Capacity at the High Air Temperature-Mid Humidity Condition

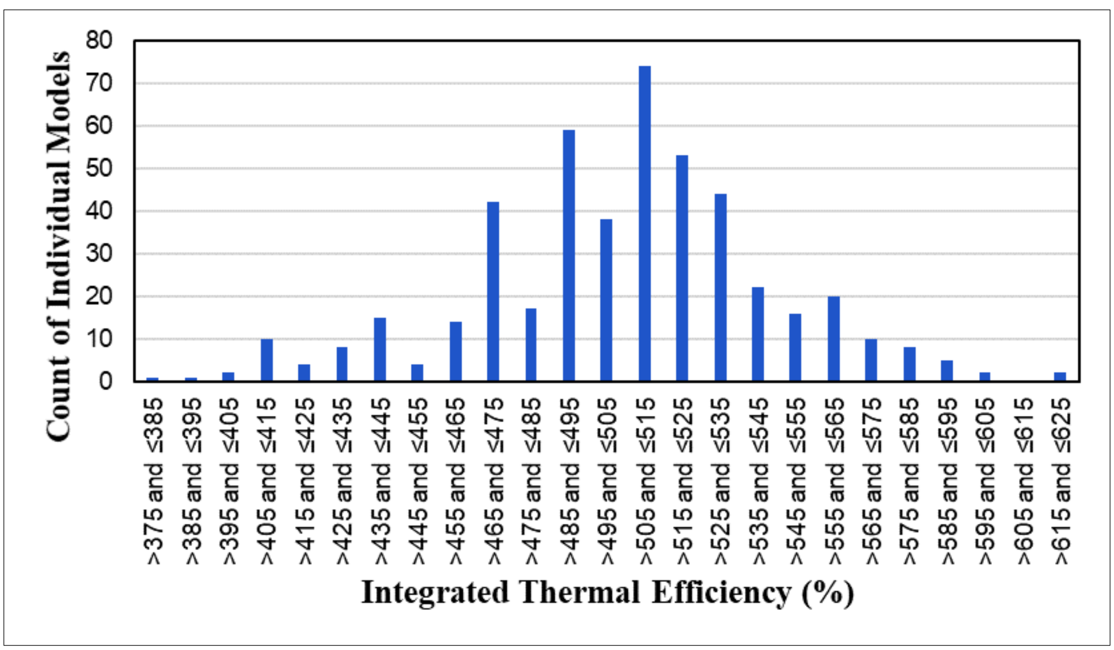


Figure 3.5.2 Distribution of Electric Heat Pump Pool Heater Individual Models by Integrated Thermal Efficiency

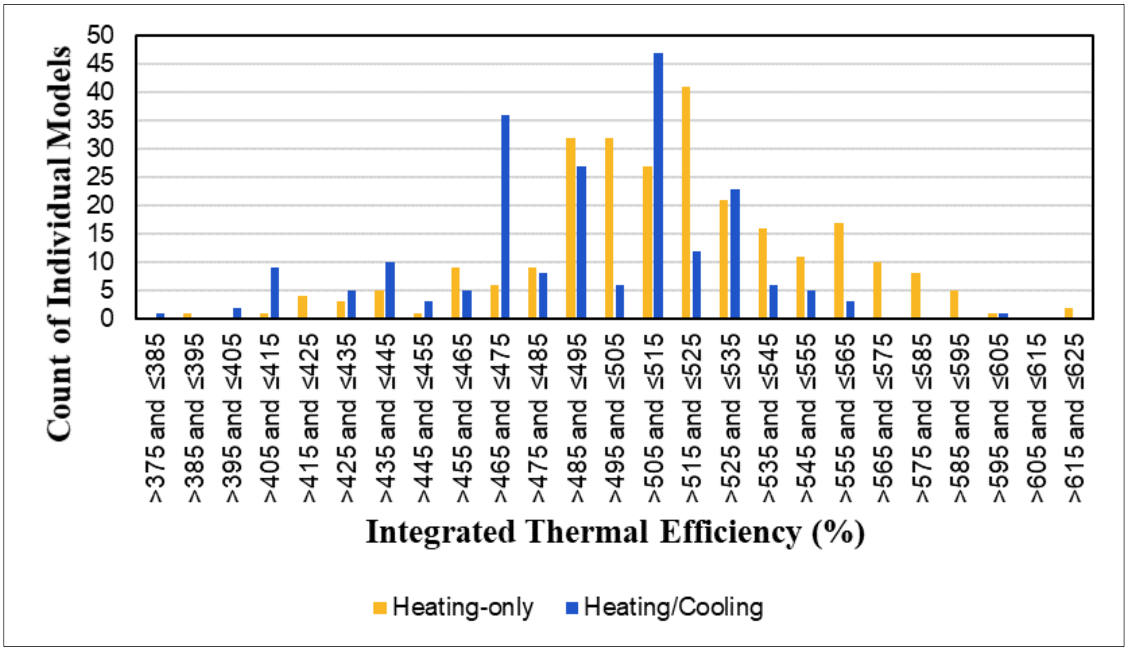


Figure 3.5.3 Distribution of Electric Heat Pump Pool Heater Individual Models by Integrated Thermal Efficiency

3.5.3.2 Gas-Fired Pool Heater

As noted in section 3.4, the DOE test procedure measures both active mode and standby and off mode energy consumption in the determination of integrated thermal efficiency. Therefore, DOE converted the thermal efficiency ratings into integrated thermal efficiency by accounting for the additional electricity use in standby and off mode and using the calculation methods in appendix P.

Figure 3.5.4 and Figure 3.5.5 show the distribution of gas-fired pool heater individual models by input capacity and integrated thermal efficiency from the database.

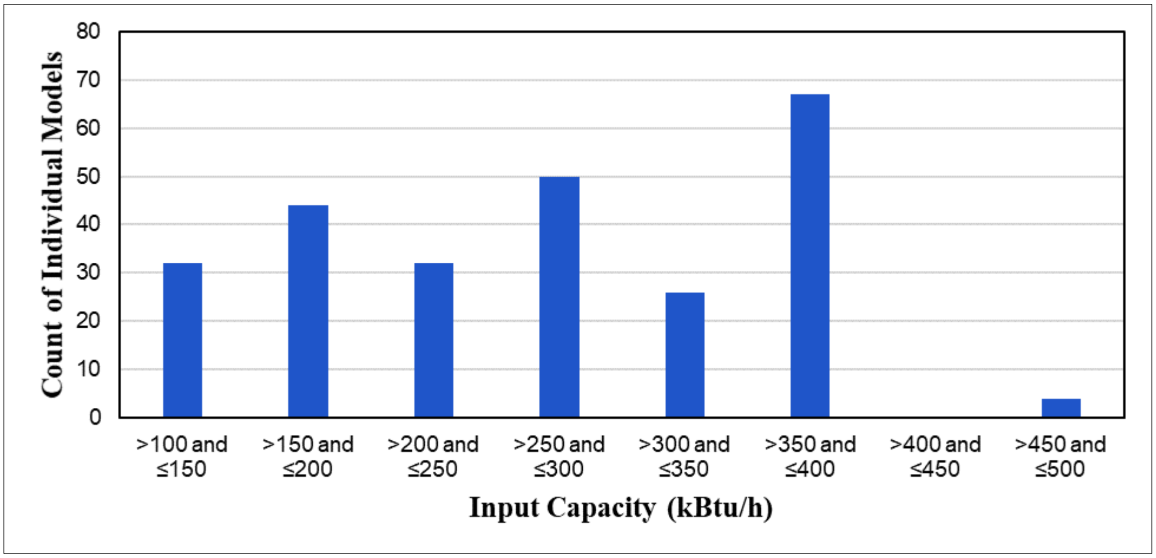


Figure 3.5.4 Distribution of Gas-Fired Pool Heater Individual Models by Input Capacity

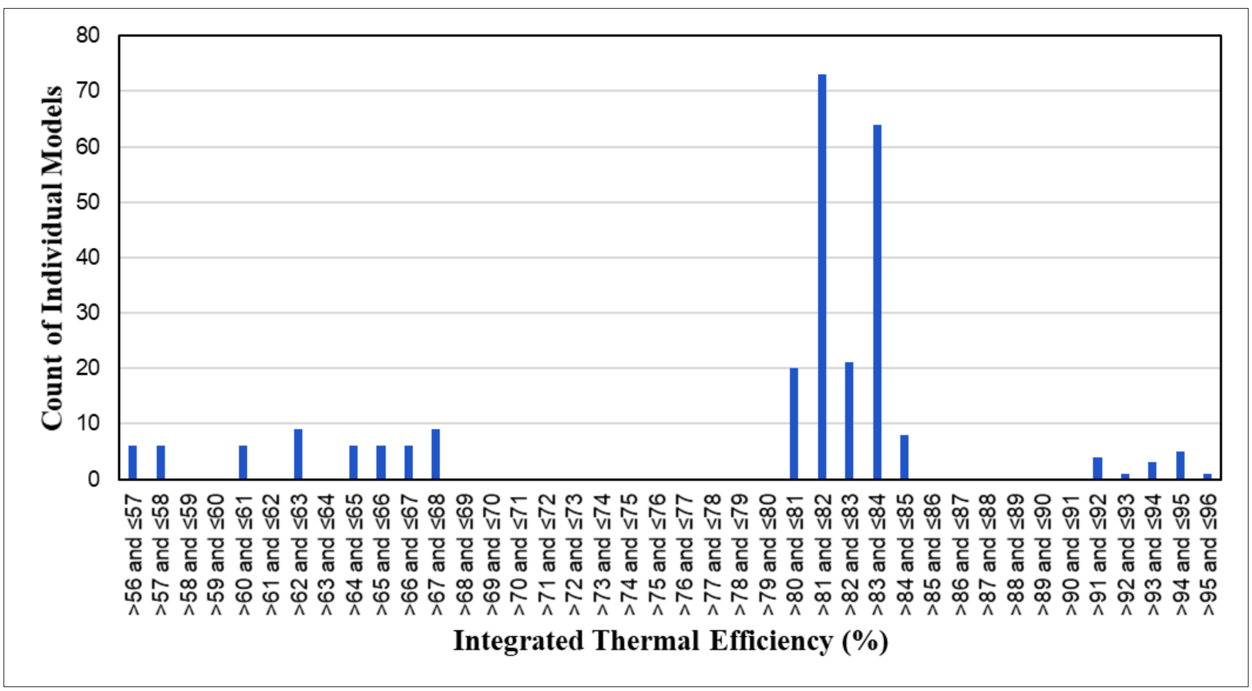


Figure 3.5.5 Distribution of Gas-Fired Pool Heater Individual Models by Integrated Thermal Efficiency

3.6 DISTRIBUTION CHANNELS

For consumer pool heaters, the main parties in the distribution chain are: (1) manufacturers; (2) wholesalers or distributors; (3) pool contractors; (4) pool retailers; (5) buying groups; and (6) pool builders. DOE models two primary markets describing the way most products pass from the manufacturer to the consumer. The first type of market applies to pool heater replacements or new owners of pool heaters with an existing swimming pool, and the second type of market applies to new swimming pool construction.

In the pool heater replacement and new owner market, the manufacturer generally sells the product to a wholesaler, who in turn sells it to either a pool contractor or pool retailer, who in turn sells it to the consumer. The pool heater wholesalers are the primary sales channel for pool heaters. Pool contractors are responsible for installing and servicing pool heaters, and they generally purchase the products from pool heater wholesalers. In another similar but less common distribution channel, pool contractors purchase the product from buying groups who are able to negotiate price reductions from manufacturers through their collective purchasing power instead of from wholesalers. In some cases, consumers purchase the pool heaters from a pool specialty store who often subcontract a pool contractor or have a service branch with licensed pool contractors to install the products for pool owners. Many of those large pool specialty stores also have direct purchase agreements with pool product manufacturers and thus serve as their own wholesalers. This type of direct retailer channel makes up a significant fraction of the pool heater retail market. In the new swimming pool construction market, the products could either be sold to a wholesaler or a buying group, who in turn sells them to a pool builder, who in turn sells them to the consumer.

For consumer pool heaters installed in commercial applications, according to manufacturer input a significant fraction go through typical distribution channels as other heating equipment in commercial applications. This includes distribution channel for which the manufacturer sells the pool heaters to the wholesaler and then to the consumer through a national account under both replacement and new construction markets. This national account distribution channel is applicable to small to mid-size commercial buildings where the on-site staff or internal personnel generally purchase equipment from wholesalers at much lower prices due to the large volume purchased and perform the installation themselves. Occasionally, the equipment manufacturers and wholesalers can be the same entity, so the consumer selling price could potentially be even lower than the usual national account channel.

Figure 3.6.1 illustrates the six distribution channels for consumer pool heaters in residential and commercial applications. Figure 3.6.2, illustrates the additional distribution channels for pool heaters in commercial applications. See chapter 6 of this TSD, for additional details and sources used to determine the typical distribution channels and market share fractions.

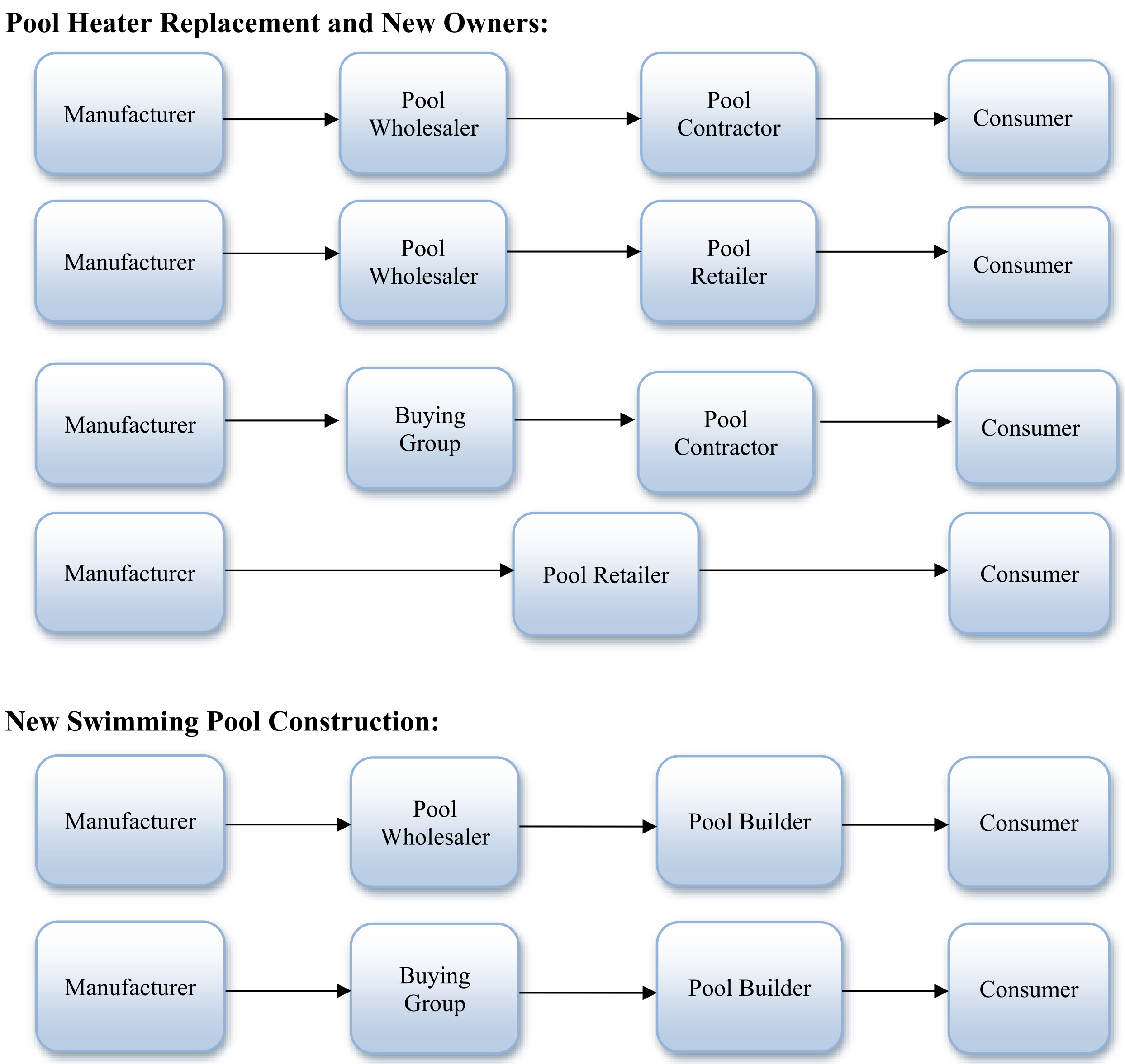
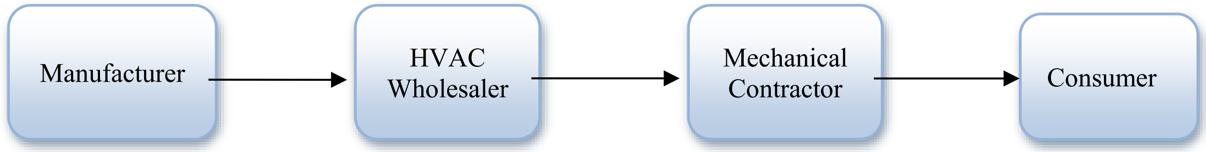


Figure 3.6.1 Distribution Channels for Consumer Pool Heaters in Residential and Commercial Applications

Replacement and New Owner:



New Construction:

National Account (for Replacement or New Construction):

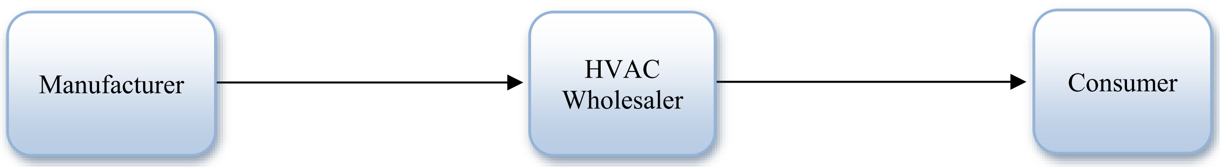


Figure 3.6.2 Additional Distribution Channels for Consumer Pool Heaters in Commercial Applications

3.7 REGULATORY PROGRAMS

The sections 3.7.1 through 3.7.2 detail the current regulatory programs that exist today for consumer pool heaters.

3.7.1 Federal Energy Conservation Standards

Title III, Part B of EPCA, sets forth a variety of provisions designed to improve energy efficiency and established the Energy Conservation Program for Consumer Products Other Than Automobiles, a program covering most major household appliances and certain industrial and commercial equipment. The National Appliance Energy Conservation Act of 1987 (NAECA), Pub. L. 100-12, amended EPCA to establish energy conservation standards for consumer pool heaters and set requirements to conduct two cycles of rulemaking to determine whether these standards should be amended. (42 U.S.C. 6295(e)(2) and (4)) The first of these two rulemakings, which included consumer water heaters, DHE, and pool heaters, concluded with a final rule which published on April 16, 2010 ("April 2010 final rule"). 75 FR 20112. With the first rulemaking, DOE amended the energy conservation standards for consumer gas-fired pool heaters. These standards are set forth in DOE's regulations at 10 CFR 430.32 and are repeated in Table 3.7.1. There are currently no federal energy conservation standards in place for electric or oil-fired pool heaters.

Table 3.7.1 Current Federal Energy Conservation Standard for Consumer Pool Heaters

Product Class	Minimum Thermal Efficiency (%)
Gas-Fired Pool Heaters	82

3.7.2 State Energy Conservation Standards

The following States have established appliance energy efficiency regulations for consumer pool heaters: California, Connecticut, and Florida. California's Code of Regulations Title 20[6], Connecticut's General Statutes Title 16A,[7] and Florida's Building Code[8] (FBC) regulate gas-fired, oil-fired, and heat pump pool heaters. The associated standards are presented in Table 3.7.2.

Table 3.7.2 State Energy Conservation Standards for Pool Heaters

State	Product Class	Standard Level		Rating Condition
		COP*	E_t (%)	
California	Gas-fired	N/A	82	N/A
	Oil-fired	N/A	78	N/A
	Heat Pump	3.5	N/A	Average of Air Temperature- Mid Humidity and Low Air Temperature-Mid Humidity
Connecticut	Gas-fired	N/A	78	N/A
	Oil-fired	N/A	78	N/A
	Heat Pump	3.5	N/A	Average of High Air Temperature-Mid Humidity and Low Air Temperature-Mid Humidity
Florida	Gas-fired	N/A	82	N/A
	Oil-fired	N/A	82	N/A
	Heat Pump	4.0	N/A	Low Air Temperature- Mid Humidity

*COP and E_t are both expressions of efficiency. To convert COP to E_t, multiply the COP value by 100% (see section 5.1.3 of appendix P).

DOE notes that the output capacity and COP of a heat pump which utilizes ambient air as a heat source is dependent upon the air temperature, air humidity, and pool water temperature at which the COP is determined. As discussed in section 3.5.3.1, typically, manufacturers test their heat pump pool heaters under one or all of the three testing conditions outlined in AHRI 1160-2014. The State standards reference the "Standard Temperature Rating" and the "Low Temperature Rating." The "Standard Temperature Rating" and "Low Temperature Rating" correspond with the "High Air Temperature-Mid Humidity" and "Low Air Temperature-Mid Humidity" rating conditions from AHRI 1160-2014, respectively.

In addition to the standards presented in Table 3.7.2, California, Connecticut, and Florida have set prescriptive standards for certain types of pool heaters. In California, Connecticut, and Florida, gas-fired pool heaters which use natural gas cannot be equipped with a constant burning pilot. In California,[9] Texas,[d,10] and Florida,[11] heat pump pool heaters must have a readily

[d] In Texas, the requirement only applies to public swimming pool and spa heaters.

accessible off switch that is mounted on the outside of the heater and that allows shutting off the heater without adjusting the thermostat setting.

3.8 HISTORICAL SHIPMENTS

Information about annual pool heater shipment trends allows DOE to estimate the impacts of a potential energy conservation standard on the pool heater industry. DOE developed shipment projections based on an analysis of key market drivers for pool heaters (chapter 9).

In the rulemaking which culminated in the April 2010 final rule, APSP provided DOE with shipment information in the form of a written comment. (EERE-2006-STD-0129, APSP, No. 135 at p. 1-2) The shipment data provided was for gas-fired pool heaters from 2003 to 2009 in two shipment classifications (<130,000 Btu/h and >130,000 Btu to <400,000 Btu/h) and is shown in Table 3.8.1. The shipment classifications are intended to separate between “above ground pools” and “in-ground pools.” The shipment information provided did not specify shipments for electric pool heaters. In addition, DOE obtained proprietary shipments data up to 2021 provided by PK Data in 2022[12] (see chapter 9 for more details).

Table 3.8.1 Gas-fired Pool Heater Shipments Provided by APSP during the April 2010 Final Rule

Year	≤130,000 Btu/h	>130,000- <400,000 Btu/h	Total
2003	15,000	153,000	168,000
2004	16,000	177,000	193,000
2005	17,000	215,000	232,000
2006	17,000	198,000	215,000
2007	14,000	171,000	185,000
2008	13,000	148,000	161,000
2009	11,000	107,000	118,000

3.9 PRODUCT LIFETIME

DOE reviewed available literature and consulted with manufacturers to establish typical product lifetimes. (See the life-cycle cost analysis, chapter 8 of this TSD, for additional details and sources used to determine the typical product lifetimes.) DOE combined these sources to develop average estimated lifetimes of the products covered by this rulemaking (Table 3.9.1).

Table 3.9.1 Product Lifetimes

Product	Average Lifetime *(years)*
Gas-fired Pool Heater	11
Electric Pool Heater	11

Chapter 8 of the TSD provides more information about pool heater lifetimes.

3.10 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a list of technology options manufacturers can use to improve the efficiency of consumer pool heaters. The following assessment provides descriptions of those technology options that apply to all pool heaters.

In preparation for the screening and engineering analyses, DOE identified several possible technology options and examined the most common efficiency-improving technologies used today. These technology options provide insight into the technological improvements typically used to increase the energy efficiency of pool heaters.

3.10.1 Baseline Product Components and Operation

The baseline model serves as a reference point for measuring changes resulting from energy conservation standards.

3.10.1.1 Electric Pool Heaters

DOE defines the baseline model as a product having an efficiency that just meets the existing Federal energy conservation standards. However, there are currently no existing Federal energy conservation standards for electric pool heaters; therefore, DOE has defined the baseline pool heater as the least energy efficient model currently available on the market.

DOE has determined the baseline electric pool heater to be electric resistance pool heaters. Electric resistance pool heaters are comprised of an outer case, electrical controls, heating elements within a vessel, a cold water inlet and a hot water outlet. An electric resistance pool heater creates heat by running an electrical current to a metal resistor which acts as a heating element. The pool water enters the pool heater and flows over the heating element and heat is transferred to the pool water.

Although manufacturers do not list efficiency metrics for electric resistance pool heaters, through testing, DOE has found that these units have a thermal efficiency of 99%.

3.10.1.2 Gas-Fired Pool Heaters

Baseline gas-fired pool heaters consist of a cold water inlet pipe, a hot water outlet pipe, a heat exchanger, a standing pilot ignition system, a pilot light sensing control valve, a burner, a combustion chamber, a flue, or vent, an air intake, a burner control thermostat, and an outer case. A gas-fired pool heater creates heat through combustion of the fuel gas and transfers it to the pool water through the heat exchanger (without direct contact between the flue gases and the pool water).

3.10.2 Technology Options for Electric Pool Heaters

DOE identified the following technology options as having the potential to improve the efficiency of electric pool heaters:

1. Improved Insulation
2. Improved Controls
3. Electric Heat Pump
    i. Increased Evaporator Surface Area
    ii. Increased Condenser Surface Area
    iii. Increased Compressor Efficiency
    iv. Expansion Valve Improvement
    v. Fan Improvements
4. Seasonal Off Switch
5. Switching Mode Power Supply

3.10.2.1 Improved Insulation

Jacket losses can be reduced by improving jacket insulation. Increasing the thermal resistivity of the jacket to reduce the amount of heat loss increases the efficiency by reducing the heat lost to the surroundings.

3.10.2.2 Improved Controls

Intelligent controls, self-diagnostics, and electronic controls can minimize energy consumption and maximize hot water output. While some of these functions may be implemented to optimize steady-state efficiency (and thus the integrated thermal efficiency metric), others are designed to improve efficiency in field use with varying usage conditions. Monitoring functions typically operate to minimize operating cost while still meeting demand. This works by tracking usage patterns and adjusting pool heater operations to maximize efficiency. Also, pool heaters may employ economizer modes to limit the maximum temperature to reduce energy consumption.

Toroidal Transformer

Because transformers continue to supply power to the control board in all modes of operation, including standby mode, increasing the operating efficiency will reduce the pool heater's standby electrical power consumption.

A toroidal transformer operates more quietly and efficiently than a typical laminated power transformer and has lower noise-inducing stray magnetic. A toroidal transformer has an annular core made of very tightly-wound, grain-oriented, silicon steel ribbons. The steel ribbons are arranged such that all their molecules are aligned with the direction of flux. This allows better performance than a traditional laminated transformer, in which unaligned molecules increase the core's resistance, or capacity for opposing magnetic induction.

Toroidal transformers also have virtually no air gap because they are made of continuously wound ribbon. Eliminating the air gab minimizes flux leakage, which is the principle source of power loss in a laminate transformer, such that nearly all flux is utilized. Additionally, toroidal transformers have a copper coating that reduces heat (*i.e.,* power) loss. Overall efficiency of a toroidal transformer is 90 to 95 percent.

However, although toroidal transformers have significant advantages over laminated transformers in efficiency, size, and weight, they are also more expensive to manufacture.

3.10.2.3 Heat Pump

A basic consumer heat pump pool heater is comprised of an outer case, electronic controls, an air-to-refrigerant heat exchanger (evaporator), a refrigerant to water heat exchanger (condenser), a compressor, an expansion device, an outdoor fan, a cold water inlet, and a hot water outlet.

Air source heat pumps transfer heat from the air to swimming pool water. Air is drawn into the heat pump and over an evaporator coil that contains a cold liquid refrigerant at low pressure. The evaporator absorbs heat from the ambient air and the refrigerant evaporates into a superheated gas prior to entering the compressor. The superheated gas then passes through a compressor, which compresses the refrigerant into a hot, highly pressurized gas. This gas is then passed through a condenser where the heat is rejected into the pool water through the use of a counterflow heat exchanger. The swimming pool water enters at the condenser, passes through a PVC pipe and washes over the condenser coil which heats the water. The heated water then exits the condenser. As the pool water heats, the condenser cools the hot high-pressure gas until it condenses into a warm liquid. Further subcooling typically also occurs. Then the warm condensed refrigerant liquid passes through an expansion device to reduce the pressure and temperature and increase the quality. It is then sent to the evaporator and the cycle repeats.

Some heat pump pool heaters feature reversing valves to reverse the direction of heat transfer. These heat pump pool heaters can act to cool the pool water when the ambient conditions are too warm and result in the pool heating up beyond the desired temperature. While the refrigerant still undergoes the same steps outlined above, the air-side heat exchanger instead acts as a condenser and the water-side heat exchanger instead acts as an evaporator. The cooling mode efficiency of heat pump pool heaters is not taken into account for integrated thermal efficiency, which is a metric that addresses heating efficiency. Thus, the heat exchanger designs which improve cooling mode efficiency are not considered in this rulemaking. Generally, cooling-capable heat pump pool heaters can reach similar efficiency levels as regular heat pump pool heaters.

3.10.2.4 Evaporator and Condenser Improvements

Most heat pump pool heaters on the market utilize traditional tube-and fin heat exchangers for their evaporator coils. These coils are refrigerant-to-air heat exchangers comprised of metals with high thermal conductivity, usually aluminum and copper, with the tubes generally being composed of copper and the fins of aluminum. The evaporator coil is responsible for evaporating and superheating the entered refrigerant liquid-vapor mixture while extracting heat from the ambient air. The internal heat-exchanging surfaces in contact with refrigerant are commonly referred to as “refrigerant-side” while the external heat-exchanging surfaces in contact with the air are referred to as “air-side.” Because a temperature difference is necessary to drive heat from the air to the refrigerant, the saturated evaporator temperature must be considerably colder than the evaporator's discharge air temperature. The magnitude of this driving force is directly related to the total load and thermal characteristic of the evaporator.

The condenser coil is responsible for condensing and subcooling the entering refrigerant vapor while rejecting heat from the refrigerant to the pool water. Most heat pump pool heaters on the market utilize titanium coils for their condenser coils.

Increased Evaporator Surface Area

Increasing the area of the evaporator coil decreases the necessary temperature difference and therefore decreases the required saturation evaporator temperature. Most approaches to increasing the coil surface area also results in an increase in the required fan motor power and an increase in the refrigerant pressure drop. Enhancements to the air side surface area include increased fin pitch (decreased fin spacing), fin patterns (wavy or zig-zag), and increased number of tube passes.

Increased Condenser Surface Area

Increasing the area of the condenser coil decreases the necessary change in temperature across the coil. Enhancements to the refrigerant side surface area typically include rifled tubing and increased number of tube passes.

3.10.2.5 Compressor Improvements

Several technologies exist to increase the efficiency of the compressors used in heat pump pool heaters. High efficiency reciprocating and scroll compressors, sometimes incorporating variable speed motors all have higher efficiencies than reciprocating compressors sometimes used in heat pump pool heaters.

Scroll compressors compress gas in a fundamentally different manner from traditional compressors – between two spirals, one fixed and one rotating. High efficiency reciprocating compressors are as efficient, or more efficient than scroll compressors. However, these compressors are often considered to present some drawbacks including noise, cost, and reliability compared to scroll compressors. Some scroll compressors come with digital modulation controls ("digital scroll compressors") to adjust capacity in response to changing load conditions, which can sometimes result in efficiency improvements.

Variable speed compressors are implemented through the use of an electronic control (an inverter drive) on the compressor motor, which allows the motor to operate at different speeds. This feature typically increases efficiency over a broad operating range but does not inherently increase maximum efficiency at the compressor rating point.

3.10.2.6 Expansion Valve Improvements

Expansion valves are refrigerant metering devices whose purpose is to control the amount of refrigerant flowing to the evaporator coil. In doing so, they simultaneously decrease the temperature and pressure of the subcooled refrigerant that enters the expansion valve, creating a cold liquid-vapor mixture. The low temperature of the refrigerant leaving the expansion valve causes the driving force to move heat from the ambient surroundings and into the evaporator.

The thermostatic expansion valve (TXV) is commonly used in heat pump pool heaters. This device uses an orifice to reduce the pressure of the entering refrigerant and a sensing bulb to monitor and maintain the temperature of the superheated vapor leaving the evaporator. Because the TXV allows for some degree of adjustment of refrigerant expansion, it may be somewhat more efficient than the capillary tube device under varying conditions.

The electronic expansion valve (EEV) is similar to the TXV but uses an electronic control system to optimize refrigeration-system performance under all operating conditions. Because it does this with greater flexibility than that allowed by a TXV, an EEV theoretically allows for further increase in energy efficiency under varying conditions when paired with advanced modulation systems. However, the energy savings due to this technology may be limited as many heat pump pool heaters operate at full capacity to satisfy the call for heat.

3.10.2.7 Fan Improvements

Fan Motor Improvements

Fan motors are fractional horsepower in size, are responsible for moving air across the coils, and typically run at one speed. The manufacturer will match the motor size and the fan blade to the coil to meet the expected load under most conditions. Higher efficiency fan motors reduces energy consumption by requiring less electrical power to generate motor shaft output power.

Electric motors operate based on the interaction between a field magnet and a magnetic rotor. In a brushed motor, the field magnets are permanent magnets and the rotor is an electromagnet, this is reversed in a brushless motor. The electromagnetic interactions between these two magnets causes the rotor to rotate.

Nearly all fan motors for standard heat pump pool heaters are permanent split capacitor (PSC). In PSC motors, the electromagnet consists of windings of electrical wire through which current is driven. Because of the capacitor, however, the current to the start-up winding is cut off as the motor reaches steady-state. PSC motors are produced in large quantities, are relatively inexpensive, and have efficiencies from 50 to 70 percent.

Electronically communicated motors (ECM) are brushless permanent magnet motors with motor efficiencies between 70 and 80 percent, making them more energy efficient than PSC motors. While PSC motors operate most efficiently at a single speed, with significantly diminishing operation efficiency at others, ECMs are capable of maintaining a high operating efficiency at multiple speeds. However, the energy savings due to this technology may be limited as many heat pump pool heaters operate at full capacity to satisfy the call for heat. ECMs are more expensive and complex than PSC motors.

Higher Efficiency Fan Blades

High efficiency fan blades move air more efficiently, yielding energy consumption savings by reducing the required fan shaft power. The fans typically used in pool heater heat pumps have stamped, curved sheet metal blades. The blades are typically supplied by a fan blade manufacturer and mounted to the motor by the manufacturer. Consequently, they are not likely to be optimized for the particular heat pump pool heater they are installed on. Fans may have lower efficiencies due to the higher required pressure drops, for which sheet metal fans are not well suited. Required fan shaft power could be reduced if the fan blades were optimized for each given application.

3.10.2.8 Seasonal Off Switch

A seasonal off switch is defined in section 1.8 of appendix P as a switch that results in different energy consumption in off mode as compared to standby mode.

The integrated thermal efficiency metric accounts for the off mode energy use consumed when the pool heater is in off mode. Off mode is defined as the condition during the pool non-heating season in which the pool heater is connected to the power source and neither the electrical resistance elements nor the heat pump is activated, and the seasonal off switch, if present, is in the "off" position. Many heat pump pool heaters do not have a seasonal off switch and the transformer is always drawing power even in off mode.

3.10.2.9 Switching Mode Power Supply

While linear power supplies regulate voltage supply to the DC circuit with a series element, switching mode power supplies (SMPS) do so in an alternative, more effective way. In a SMPS, power-handling electronics switch on and off (where on means the switch is closed and voltage drop is negligible, and off means the switch is open and current is negligible) with high frequency. This effectively connects or disconnects the output (load) to the input source. Continuous power flow to the load can be maintained and controlled by varying the duty cycle or frequency of the SMPS.

Linear power supplies experience significant heat losses because they use resistance elements, which convert electrical energy to heat energy, to regulate power supply. By using a switch to control energy flow instead, switching mode power supplies avoid such heat losses and have much higher efficiency. SMPS do introduce transient losses that increase with frequency, but these losses are negligible in comparison with the energy saved. Thus, replacing a linear power supply with an SMPS has the potential to reduce the electrical power consumption of consumer pool heaters in standby and off mode.

3.10.3 Technology Options for Gas-Fired Pool Heaters

DOE identified the following technology options as having the potential to improve the efficiency of gas-fired pool heaters:

1. Improved Insulation (combustion chamber)

2. Improved Controls
3. Electronic Ignition
4. Improved Heat Exchanger
5. Condensing
6. Condensing Pulse Combustion
7. Seasonal Off Switch
8. Switching Mode Power Supply

3.10.3.1 Insulation of Combustion Chamber

Combustion chambers for pool heaters are insulated with fiberglass blankets to prevent heat loss through the walls of the combustion chamber to the exterior of the pool heater. Manufacturers reduce the amount of heat loss to increase the thermal efficiency by using materials with more effective insulation properties. Pool heater manufacturers currently produce products that use Fiberfrax panels and refractory tiles to reduce the amount of heat loss through the combustion chamber walls. By lining the sides and bottom of the heat exchanger with these materials, manufacturers increase the amount of heat that is transferred from the combustion chamber to the heat exchanger. DOE identified several manufacturers that use insulation that is more effective than fiberglass blankets for pool heater combustion chambers.

3.10.3.2 Electronic Ignition

One of the most common ways to reduce energy consumption of pool heaters is to eliminate the standing pilot light as a method of igniting the main burner. Pool heater manufacturers already make heaters with electronic ignition and many different variations in models are available. Since February 1984, California has required that natural gas-fired pool heaters use electronic ignition instead of standing pilot lights. Three electronic ignition devices are used in gas-fired pool heaters:

Intermittent Pilot Ignition. This device lights a pilot by generating a spark, which in turn lights the main burner.

Intermittent Direct Ignition. This system lights the main burner directly by generating a spark.

Hot Surface Ignition. This system lights the main burner directly from a sufficiently hot surface.

Unlike standing pilot ignition systems that consume gas continuously, these devices operate only at the beginning of each on-period. Although there is no increase in the steady-state efficiency when using electronic ignition devices, the overall fuel consumption is reduced. Pool heater pilot lights typically consume approximately 1,000 Btu/h on average. Because of this, electronic ignition significantly improves the standby fuel consumption of the pool heater and yields substantial increases to integrated thermal efficiency.

3.10.3.3 Improved Controls

The improved controls discussion for electric pool heaters from section 3.10.2.2 also applies to gas-fired pool heaters. Diagnostic software may also maintain the optimal burner conditions, valve positions, and air-to-fuel ratios to maximize efficiency.

3.10.3.4 Improved Heat Exchanger

Gas-fired pool heaters are currently capable of reaching the steady-state efficiency level where potentially damaging condensation will start to form on the heat exchanger. A small increase in heat exchanger size may be possible without causing condensation of the combustion gases by increasing the heat exchanger surface area. The burner configuration might also require adjustment. No blower would be required for this technology option.

The heat exchanger size can also be increased while preventing condensation from forming by using a governor. The governor maintains pool water temperature and water flow to prevent condensation of combustion gases. The governor limits the efficiency of the heat exchanger so that the latent heat of the combustion gases is not transferred to the pool water. At least one manufacturer makes a pool heater with a condensing governor.

If condensation is desired to achieve a high steady-state efficiency, then the pool heater design must properly manage and dispose of the potentially damaging condensate. This can be accomplished with corrosion-resistant materials and a condensate drain.

Before achieving condensing levels, the heat exchange can be improved through the use of a blower.

3.10.3.5 Condensing

To increase the efficiency of a pool heater, the water vapor in the combustion gases must be condensed in order to capture the heat of vaporization. The heat exchanger must be altered for condensing operations to prevent condensate from corroding the heat exchanger. A condensate drain is also required.

3.10.3.6 Condensing Pulse Combustion

Pulse combustion burners operate on self-sustaining resonating pressure waves that alternately rarefy the combustion chamber (drawing a fresh fuel/air mixture into the chamber) and pressurize it (causing ignition by compression heating of the mixture to its flash point). This process is initiated by a blower supplying an initial fuel and air mixture to the combustion chamber. A spark ignites the mixture. Once resonance is initiated, the process becomes self-sustaining.

Pulse combustion systems feature high heat transfer rates, can self-vent, and can draw outside air for combustion even when installed inside. Because the pulse combustion process is highly efficient, the burners are generally used with condensing appliances.

3.10.3.7 Seasonal Off Switch

The integrated thermal efficiency metric accounts for the off mode energy use consumed when the pool heater is in off mode. Off mode is defined as the condition during the pool non-heating season in which the pool heater is connected to the power source and the main burner is not activated, and the seasonal off switch, if present, is in the "off" position.

3.10.3.8 Switching Mode Power Supply

The SMPS discussion for electric pool heaters from section 3.10.2.9 also applies to gas-fired pool heaters.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter discusses the screening analysis conducted by the U.S. Department of Energy (DOE) of the technology options identified in the market and technology assessment for pool heaters (chapter 3 of this technical support document (TSD)). In the market and technology assessment, DOE presented an initial list of technology options that can be used to improve the integrated thermal efficiency of pool heaters. The goal of the screening analysis is to identify any technology options that will be eliminated from further consideration in the rulemaking analyses.

DOE must follow specific statutory criteria for prescribing new or amended standards for covered products. The Energy Policy and Conservation Act (EPCA) requires that any new or amended energy conservation standard prescribed by the Secretary of Energy ("Secretary") be designed to achieve the maximum improvement in energy or water efficiency that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) The Secretary may not prescribe an amended or new standard that will not result in significant conservation of energy, or is not technologically feasible or economically justified. (42 U.S.C. 6295(o)(3)) As stated, DOE determines whether to eliminate certain technology options from further consideration based on the following criteria:

(1) Technological feasibility. If it is determined that a technology has not been incorporated in commercial products or in working prototypes, then that technology will not be considered further.

(2) Practicability to manufacture, install and service. If it is determined that mass production of a technology in commercial products and reliable installation and servicing of the technology could not be achieved on the scale necessary to serve the relevant market at the time of the effective date of the standard, then that technology will not be considered further.

(3) Adverse Impacts on Product Utility or Product Availability. If a technology is determined to have significant adverse impact on the utility of the product to significant subgroups of consumers, or results in the unavailability of any covered product type with performance characteristics (including reliability), features, size, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not be considered further.

(4) Adverse Impacts on Health or Safety. If it is determined that a technology will have significant adverse impacts on health or safety, it will not be considered further.

(5) Unique-Pathway Proprietary Technologies. If a technology option uses proprietary technology that represents a unique pathway to achieving a given efficiency level, that technology will not be considered further.

10 CFR part 430, subpart C, appendix A, 6(c)(3) and 7(b).

The candidate technology options are assessed based on DOE analysis as well as inputs from interested parties, including manufacturers, trade organizations, and energy efficiency advocates. Technology options that are judged to be viable approaches for improving energy efficiency are retained as inputs to the subsequent engineering analysis, and are designated as "design options."

4.2 DISCUSSION OF TECHNOLOGY OPTIONS

For pool heaters, the screening analysis criteria were applied to the technology options to determine whether to retain or eliminate each technology from the engineering analysis. The rationale for either screening out or retaining each technology option considered in this analysis is detailed in the following sections.

4.2.1 Screened-Out Technologies

This section describes the technology options that DOE eliminated for failure to meet one of the following five factors described in section 4.1. Based on DOE's research and consideration of comments received from interested parties, DOE screened out only one technology: condensing pulse combustion for gas-fired pool heaters.

As described in chapter 3, pulse combustion burners operate on self-sustaining resonating pressure waves that alternately rarefy the combustion chamber. Pulse combustion systems are capable of self-venting, and can draw outside air for combustion even when installed inside. Although condensing pulse combustion technology shows promising results in increasing efficiency, it has not yet penetrated the pool heater market, and DOE notes that similar efficiencies are achievable with other technologies that have already been introduced on the market. Therefore, DOE has determined it is not technologically feasible and not practicable to manufacture, install, and service condensing pulse combustion technology on the scale necessary to serve the relevant market at the time of the effective date of this standard.

4.2.2 Remaining Technologies

The technology options for pool heaters that were retained by DOE and subsequently evaluated further in the engineering analysis are listed in sections 4.2.2.1 and 4.2.2.2 below.

4.2.2.1 Electric Pool Heaters

DOE retained the following technologies in evaluating improved integrated thermal efficiency for electric pool heaters:

1. Improved Insulation
2. Improved Controls
3. Heat Pump
   i. Increased Evaporator Surface Area
   ii. Increased Condenser Surface Area
   iii. Increased Compressor Efficiency
   iv. Expansion Valve Improvement
   v. Fan Improvements
4. Seasonal Off Switch
5. Switch Mode Power Supply
6. Transformer Improvements

4.2.2.2 Gas-Fired Pool Heaters

DOE retained the following technologies in evaluating improved integrated thermal efficiency for gas-fired pool heaters:

1. Improved Insulation (combustion chamber)
2. Improved Controls
3. Electronic Ignition
4. Improved Heat Exchanger
5. Condensing
6. Seasonal Off Switch
7. Switch Mode Power Supply
8. Transformer Improvements

CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

This chapter provides an overview of the engineering analysis (section 5.1), discusses product classes and representative capacities (section 5.2 and 5.3), establishes baseline and incremental efficiency levels (section 5.4), describes the cost analysis methodology (section 5.5), and discusses the analysis and results (sections 5.6 through 5.9).

5.1 INTRODUCTION

After conducting the screening analysis, the U.S. Department of Energy (DOE) performed an engineering analysis based on the remaining design options. There are two dimensions to consider in the engineering analysis; the selection of efficiency levels to analyze (*i.e.*, the "efficiency analysis") and the determination of product cost at each efficiency level (*i.e.*, the "cost analysis").

The efficiency analysis can be conducted using either the efficiency-level approach, the design-option approach, or a combination of both. Using the efficiency-level approach, the efficiency levels to be considered in the analysis are determined based on the market distribution of existing products (in other words, looking at the range of efficiency and efficiency level "clusters" that already exist on the market). This approach typically starts with compiling a comprehensive list of products available on the market, such as from DOE's product certification database. Next, the list of models is ranked by efficiency level from lowest to highest, and DOE typically creates a scatter plot to visualize the distribution of efficiency levels. From these rankings and visual plots, efficiency levels can be identified by examining clusters of models around common efficiency levels. The maximum efficiency level currently available on the market can also be identified.

Under the design option approach, the efficiency levels to be considered in the analysis are determined through detailed engineering calculations and/or computer simulations of the efficiency improvements from implementing specific design options that have been identified in the technology assessment. (In an iterative fashion, design options can also be identified during product teardowns, described below). The design option approach is typically used when a comprehensive database of certified models including the energy efficiency is unavailable (for example, if a product is not yet regulated) and therefore the efficiency-level approach cannot be used.

In certain rulemakings, the efficiency-level approach (based on actual products on the market) will be extended using the design option approach to interpolate to define "gap fill" levels (to bridge large gaps between other identified efficiency levels) and/or to extrapolate to the "max tech" level (the level that DOE determines is the maximum achievable efficiency level, particularly in cases where the "max tech" level exceeds the maximum efficiency level currently available on the market).

The cost analysis portion of the engineering analysis is conducted using one or a combination of cost approaches. The selection of the cost approach depends on a suite of factors, including availability and reliability of public information, characteristics of the regulated product, availability and timeliness of purchasing the product on the market. The cost approaches are summarized as follows:

- Physical teardown: Under this approach, DOE physically dismantles a commercially available product, component-by-component, to develop a detailed bill of materials (BOM) for the product.

- Catalog teardown: In lieu of physically deconstructing a product, DOE identifies each component using parts diagrams (available from manufacturer websites or appliance repair websites, for example) to develop the BOM for the product.

- Price surveys: If neither a physical nor catalog teardown is feasible (for example, for tightly integrated products that are infeasible to disassemble and for which parts diagrams are unavailable), DOE conducts retail price surveys using publicly available pricing data published on major online retailer websites and/or by soliciting prices from distributors and other commercial channels. This approach must be coupled with assumptions regarding distributor markups and retailer markups in order to estimate the actual manufacturing cost of the product.

The primary inputs to the engineering analysis are baseline information from the market and technology assessment (chapter 3 of this technical support document (TSD) for this final rule and technology options from the screening analysis (chapter 4 of this TSD). Additional inputs were determined through teardown analysis and manufacturer interviews.

To establish the industry cost-efficiency curves for consumer pool heaters for this final rule, DOE used the efficiency level approach to identify incremental improvements in efficiency for each product class, and used physical and catalog teardowns to develop a cost for each efficiency level. DOE identified common consumer pool heaters on the market and determined their corresponding efficiency levels, the component specifications, and the distinguishing technology features associated with those levels. After identifying the most common products that represent a cross section of the market, DOE gathered additional information using reverse engineering (*i.e.*, teardown) methodologies, product information from manufacturer catalogs, and discussions with experts and manufacturers of consumer pool heaters. This approach provided useful information, including identification of potential technology paths manufacturers use to increase energy efficiency. As discussed in detail later in this chapter, DOE generated bills of materials (BOM) for products at various efficiency levels by disassembling multiple manufacturers' products spanning a range of efficiency levels. The BOMs describe the product in detail, including all manufacturing steps required to make and/or assemble each part. Subsequently, DOE used information from the BOMs to estimate the manufacturer production cost (MPC) to produce each unit. As a final step in the engineering analysis, DOE derived manufacturer markups and applied them to the MPCs to calculate manufacturer selling prices (MSP) at each efficiency level and generated cost-efficiency curves.

The primary output of the engineering analysis is a set of cost-efficiency curves. In the subsequent markups analysis (chapter 6 of this TSD), DOE determined customer (*i.e.*, product purchaser) prices by applying distribution markups, sales tax and contractor markups. After applying these markups, the cost-efficiency curves serve as the input to the building energy-use and end-use load characterization (chapter 7 of this TSD), and the life-cycle cost (LCC) and payback period (PBP) analyses (chapter 8 of this TSD).

5.2 PRODUCT CLASSES

When evaluating energy conservation standards, DOE may establish separate standards for a group of covered products (*i.e.*, establish a separate product class) if DOE determines that separate standards are justified based on the type of energy used, or if DOE determines that a product's capacity or other performance-related feature justifies a different standard. (42 U.S.C. 6295(q)(1)(A) and (B)) In making a determination whether a performance-related feature justifies a different standard, DOE must consider factors such as the utility to the consumer of the feature and other factors DOE determines are appropriate. (42 U.S.C. 6295(q)(1))

DOE regulations currently set a standard for only one class of consumer pool heaters: gas-fired pool heaters. (10 CFR 430.32(k)) Although energy conservation standards for consumer pool heaters that rely on other fuel types (*e.g.*, oil or electricity) have not been established, as discussed in the final rule, the definition for pool heaters found at 42 U.S.C. 6291(25)[a] does not specify a fuel type, and therefore electric and oil-fired pool heaters are also covered products under EPCA. DOE separated consumer pool heaters into product classes as shown in Table 5.2.1 for the final rule analysis.

Table 5.2.1 Consumer Pool Heaters Product Classes

Product Class	Analyzed
Gas-fired	Yes
Oil-fired	No
Electric Pool	Yes
Electric Spa*	No

* For this analysis electric spa heaters were defined as pool heaters that use electricity as the primary energy source, have a rated output capacity of 11 kilowatts or less, and are designed to be installed within a portable electric spa.

DOE did not analyze electric spa heaters in the engineering analysis, because DOE did not identify any technology options that would have measurable effect on the integrated thermal efficiency of these units. DOE also did not analyze potential standards for oil-fired pool heaters based on its previous understanding that the market for oil-fired pool heaters is extremely limited and, thus, any standards would be unlikely to result in significant energy savings. DOE reviewed only gas-fired pool heaters and electric pool heaters for the engineering analysis.

5.3 REPRESENTATIVE CAPACITIES

Capacity is a factor that influences both the integrated thermal efficiency rating and the MPC of a consumer pool heater. The impact of efficiency ratings on consumer pool heater prices

[a] The Energy Policy and Conservation Act (EPCA) defines the term "pool heater" as "an appliance designed for heating nonpotable water contained at atmospheric pressure, including heating water in swimming pools, spas, hot tubs and similar applications." (42 U.S.C. 6291(25))

can be captured by calculating the incremental price for each efficiency level higher than the baseline at a given capacity.

To provide a singular set of incremental cost-efficiency results for the engineering analysis that would clearly reflect the cost delta for improving efficiency at a given capacity, DOE selected a single capacity to represent all consumer pool heaters of a given product class. DOE selected 110 kBtu/h to be the representative output capacity for electric pool heaters and 250 kBtu/h to be the representative input capacity for gas-fired pool heaters. DOE selected these capacities by referencing a number of sources, including information obtained during manufacturer interviews, information collected for the market and technology assessment, as well as information obtained from consumer pool heater product literature. The representative capacity for each class is based on consumer pool heater capacities that had a large number of models on the market, and that DOE estimates have high numbers of shipments. Table 5.3.1 shows the representative capacities used in the analysis for consumer pool heaters.

Table 5.3.1 Representative Capacity for Electric and Gas-Fired Pool Heaters

Pool Heater Type	Representative Output Rating (Btu/h)	Representative Input Rating (Btu/h)
Electric Pool Heater	110,000	n/a
Gas-Fired Pool Heater	n/a	250,000

5.4 EFFICIENCY LEVELS

For consumer pool heaters, DOE analyzed multiple efficiency levels and estimated the manufacturer production costs at each of these levels. The following subsections discuss the full efficiency level range from the baseline efficiency level to the maximum technologically feasible efficiency level.

The DOE efficiency metric determined by the test procedure found at 10 CFR 430 Subpart B, Appendix P (“appendix P”) is integrated thermal efficiency, which takes into account active mode energy use, as well as standby and off mode energy use. This rulemaking would serve as the first energy conservation standards rulemaking subsequent to the test procedure amendments that established the integrated thermal efficiency metric, and therefore this analysis takes into account standby and off mode energy consumption.

The integrated thermal efficiency metric is the ratio of the seasonal useful output of the pool heater divided by the annual input to the pool heater, and is expressed by the following equation:

$$TE_i = 100\left(\frac{BOH\left[\left({}^{E_t}/_{100}\right)(Q_{IN} + PE)\right]}{E_F + E_{AE}}\right)$$

Where:

TE_i = integrated thermal efficiency
BOH = average annual number of burner operating hours,

E_t = thermal efficiency as defined in section 5.1 of appendix P,
Q_{IN} = rated fuel energy input as defined according to section 2.10.1 or section 2.10.2 of ANSI, Z21.56, Btu/h,
PE = hourly electrical power consumption, Btu/h,
E_F = the average annual fossil fuel energy, Btu, and
E_{AE} = average annual electricity consumption, Btu.

E_F and E_{AE} are calculated using the following equations:

$$E_F = BOH * Q_{IN} + (POH - BOH)Q_{PR} + (8760 - POH)Q_{off.R}$$

$$E_{AE} = E_{AE,active} + E_{AE,standby,off}$$

$$E_{AE,active} = BOH * PE$$

$$E_{AE,standby,off} = (POH - BOH)P_{W,SB} + (8760 - POH)P_{W,OFF}$$

Where:

BOH = as defined above
Q_{IN} = as defined above
POH = average number of pool operating hours, h,
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, Btu/h,
8760 = number of hours in one year, h,
$Q_{off,R}$ = average off mode fossil fuel energy consumption rate, Btu/h,
$E_{AE,active}$ = electrical consumption in the active mode, Btu,
$E_{AE,standby,off}$ = auxiliary electrical consumption in the standby and off mode, Btu,
$P_{W,SB}$ = electrical energy consumption rate during standby mode, Btu/h, and
$P_{W,OFF}$ = electrical energy consumption rate during off mode, Btu/h.

Many of the inputs into the integrated thermal efficiency metric, such as standby mode electricity and fuel consumption, as well as the off mode electricity and fuel consumption, are not expected to increase as capacity increases. This causes differences in the resulting integrated thermal efficiencies for units with the same thermal efficiency (or coefficient of performance (COP) in the case of heat pump pool heaters). Specifically, lower capacity units will have lower integrated thermal efficiency ratings due to the fact that the standby and off mode energy use comprise a larger share of the total energy use of the appliance than it does for larger capacity units.

The most extreme example of this occurs in gas-fired pool heaters with standing pilot lights. The standing pilot light is assumed to consume 1,000 Btu/h regardless of capacity. As an example, the integrated thermal efficiency of a 100 kBtu/h rated input capacity gas-fired pool heater with a thermal efficiency of 82% and a standing pilot would be approximately 45%, whereas the integrated thermal efficiency of a 400 kBtu/h rated input capacity gas-fired pool heater with a thermal efficiency of 82% and a standing pilot is approximately 68%.

To account for this, rather than analyzing fixed integrated thermal efficiency levels as was done in the preliminary analysis, DOE developed equation-based efficiency levels that express the integrated thermal efficiency level as a function of capacity.

To inform the engineering analysis and establish efficiency levels, DOE combined information from DOE's Compliance Certification Management System Compliance Certification Database (CCD)[1] with data from the Air-Conditioning, Heating, and Refrigeration Institute's (AHRI) Directory of Certified Product Performance of Heat Pump Pool Heaters ("AHRI Directory")[2] and data from publicly available manufacturers' catalogs to develop a comprehensive database of consumer pool heaters ("PH database"). DOE used the rated COP and thermal efficiency levels in its PH database as well as typical values for standby mode and off mode energy consumption in order to calculate integrated thermal efficiencies for all electric and gas-fired pool heaters. DOE derived estimates for standby and off mode energy consumption from tested values and sought manufacturer feedback during confidential manufacturer interviews to confirm that the values were typical.

The energy consumption rate measurements that feed into the integrated thermal efficiency metric are outlined in Table 5.4.1 below and vary by consumer pool heater type (*i.e.,* electric resistance, heat pump, and gas-fired) and by efficiency level. The assumptions made for each of the energy consumption rate measurements are discussed in the sections below.

Table 5.4.1 Inputs to Integrated Thermal Efficiency by Consumer Pool Heater Type

Type	Inputs to TE_i	Input Description
All	BOH	Average number of burner operating hours = 104 h
	POH	Average number of pool operating hours = 4,464 h
	$P_{W,SB}$	Standby power consumption rate, Btu/h
	$P_{W,OFF}$	Off power consumption rate, Btu/h
Electric Resistance Pool Heater	E_t	Thermal Efficiency (11.1 of ASHRAE 146)
	Q_{IN}	Rated fuel energy input = 0 Btu/h
	PE	Hourly electrical consumption in active mode, Btu/h = $2*E_c$
	E_c	Electrical consumption per 30 min, Btu
	Q_{PR}	Consumption rate of pilot = 0 Btu/h
	$Q_{off,R}$	Off mode fuel consumption rate = 0 Btu/h
Heat Pump Pool Heater	E_t	Thermal Efficiency (11.1 of ASHRAE 146)
	Q_{IN}	Rated fuel energy input = 0 Btu/h
	PE	Hourly electrical consumption In Active Mode Btu/h = $E_{c,HP}*(60/t_{HP})$
	$E_{c,HP}$	Electrical consumption during test time, Btu
	t_{HP}	Test time, min
	Q_{PR}	Consumption rate of pilot = 0 Btu/h
	$Q_{off,R}$	Off mode fuel consumption rate = 0 Btu/h
Gas-Fired Pool Heater	E_t	Thermal Efficiency (2.10 of ANSI Z21.56)
	Q_{IN}	Rated fuel energy input, Btu/h
	PE	Hourly electrical consumption in active mode, Btu/h = $2*E_c$, if tested to 2.10.1 of ANSI Z21.56 = $3.412*PE_{rated}$, if tested to 2.10.2 of ANSI Z21.56
	E_c	Electrical consumption per 30 min, Btu
	PE_{rated}	Nameplate rating of auxiliary electrical equipment, W
	Q_{PR}	Consumption rate of pilot = 1,000 Btu/h
	$Q_{off,R}$	Off mode fuel consumption rate, Btu/h

The definitions for standby and off mode are outlined in section 1 of Appendix P to subpart B of part 430 and are repeated below.

Active mode means the condition during the pool heating season in which the pool heater is connected to the power source, and the main burner, electric resistance element, or heat pump is activated to heat pool water.

Off mode means the condition during the pool non-heating season in which the pool heater is connected to the power source, and neither the main burner, nor the electric resistance elements, nor the heat pump is activated, and the seasonal off switch, if present, is in the "off" position.

Seasonal off switch means a switch that results in different energy consumption in off mode as compared to standby mode.

Standby mode means the condition during the pool heating season in which the pool heater is connected to the power source, and neither the main burner, nor the electric resistance elements, nor the heat pump is activated.

For the calculations to establish integrated thermal efficiency levels DOE estimated the annual active mode duration, off mode duration, and standby mode duration based on assumed values in the consumer pool heater test procedure at appendix P. The annual active mode duration (*i.e.*, BOH) is estimated to be 104 hours. The annual off mode duration is estimated to be 4296 hours, which is calculated as the total hours in a year, 8760, minus 4464 hours, which is the average annual number of pool operating hours (*i.e.*, POH). The annual standby mode duration is estimated to be the average annual number of pool operating hours (POH), 4464, minus the active mode hours (BOH), 104, and equals 4360 hours.

For consumer pool heaters with a seasonal off switch, the average electric power consumption during the off mode, $P_{W,OFF}$, is 0, and the fossil fuel energy consumed during the off mode, Q_{off}, is 0.

For consumer pool heaters without a seasonal off switch, the average electrical power consumption during the off mode, $P_{W,OFF}$, is equal to the average electrical power consumption during standby mode, $P_{W,SB}$. Although many consumer pool heaters may come equipped with an off switch to be in compliance with State regulations, as discussed in chapter 3 of this TSD, the off switches required by State regulations are not required to reduce the standby power consumption, as the definition specified by DOE would require. Based on its own product testing, DOE has determined that it was not appropriate to assume that all consumer pool heaters with off switches had seasonal off switches, as defined by DOE. For fossil fuel energy consumption during the off mode test Q_{off} equals Q_p.

As noted above all other values needed to calculate the integrated thermal efficiency at each efficiency level were determined based on ratings data from DOE’s PH database and based on test data for standby mode and off mode. These values are shown in Table 5.4.2 and Table 5.4.3.

5.4.1 Baseline Efficiency Levels

DOE selected a baseline model to act as a reference point for consumer pool heaters in a given product class, against which DOE measured changes resulting from potential amended energy conservation standards. A baseline model represents the basic characteristics of products in a given product class. Typically, a baseline model is a model that just meets current Federal energy conservation standards and provides basic consumer utility. For gas-fired pool heaters, the least efficient model utilizes a standing pilot light and has a thermal efficiency of 82%.

Since standards are not yet established for electric pool heaters, DOE selected a baseline model that represents the least efficient electric pool heater currently found on the market. For electric pool heaters, the least efficient model employs electric resistance heater elements. These units typically have a thermal efficiency of 99%.

The baseline models identified in the engineering analysis represent the energy efficiency and cost of the typical minimum technology product on the market. DOE used this baseline efficiency for the subsequent analyses (*e.g.*, life-cycle cost (LCC), payback period (PBP), national impact analysis (NIA), manufacturer impact analysis (MIA), etc.). To determine energy savings and changes in price, DOE compared higher energy efficiency levels with the baseline model.

5.4.2 Intermediate Efficiency Levels

DOE selected several efficiency levels between the baseline efficiency level and the max-tech efficiency level for analysis. The efficiency levels represent the most common efficiencies on the market or a major design change (*i.e.,* switching from electric resistance to heat pump technology). The efficiency levels were selected based on an extensive review of publicly available product literature as well as the PH database that DOE compiled.

When selecting efficiency levels for standards analysis, DOE considered the efficiency that would result from testing according to the appendix P. DOE recognizes that in certain instances, units may be operated in a different manner in the field than assumed in the "typical" energy values used for the test procedure calculations. For example, a certain percentage of consumer pool heaters without an off switch would likely be winterized and turned off via a circuit breaker, and while they may have no off mode consumption in the field, the test procedure requires that for their efficiency rating, the off mode consumption be assumed to be the same as the standby mode consumption. These considerations are examined in the energy use analysis and are described in Chapter 8 of this TSD. However, they are not accounted for in the engineering analysis, as the focus is the energy efficiency as it would be rated under the test procedure.

Table 5.4.2 shows the efficiency levels analyzed in the final rule analysis for electric pool heaters. The standby and off mode electricity consumption rate selected for each efficiency level was based on typical values measured during DOE product testing. Figure 5.4.1 shows the integrated thermal efficiency equations from Table 5.4.2 across the entire available output capacity range.

DOE determined via product testing that electric resistance pool heaters have lower standby and off mode values than do heat pump pool heaters. DOE research suggests that the standby and off mode electricity consumption are largely driven by the transformer and are expected to be similar throughout all heat pump efficiency levels. DOE added technology options to reduce the standby and off mode electricity consumption to achieve the max-tech level for electric pool heaters.

Table 5.4.2 Efficiency Levels for Electric Pool Heaters

Efficiency Level	E_t (%)*	$P_{W,SB}$ (W)**	$P_{W,OFF}$ (W)**	Integrated Thermal Efficiency (%)
EL 0	99	1.2	1.2	$TE_i = \frac{99\ PE}{PE + 341}$
EL 1	360	5.7	5.7	$TE_i = \frac{410\ PE}{PE + 1{,}619}$
EL 2	520	5.7	5.7	$TE_i = \frac{520\ PE}{PE + 1{,}619}$
EL 3	580	5.7	5.7	$TE_i = \frac{580\ PE}{PE + 1{,}619}$
EL 4	600	5.7	5.7	$TE_i = \frac{600\ PE}{PE + 1{,}619}$
EL 5†	610	3.1	0.0	$TE_i = \frac{610\ PE}{PE + 443}$

*As defined by section 5.1 of appendix P.
** Presented in terms of Btu/h in appendix P.
† The max-tech efficiency level includes standby and off mode technology options.

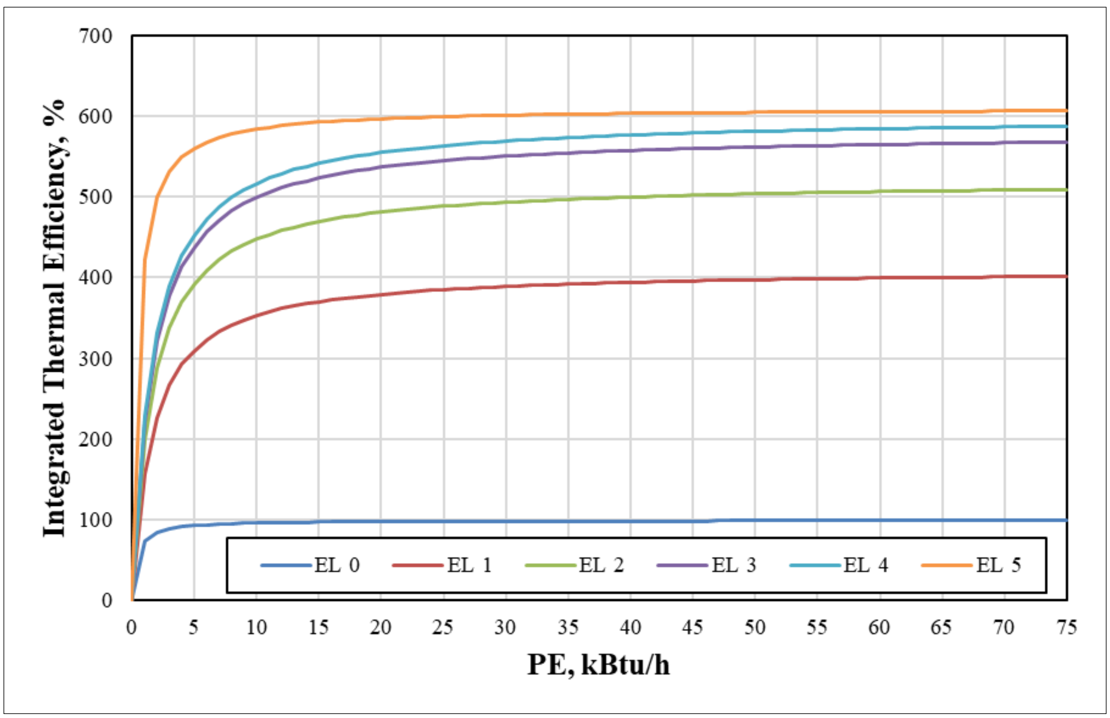

Figure 5.4.1 Efficiency Levels for Electric Pool Heaters

Table 5.4.3 shows the efficiency levels analyzed in the final rule analysis for gas-fired pool heaters. The standby and off mode electricity consumption rate selected for each efficiency level was based on typical values measured during DOE product testing.

Table 5.4.3 Efficiency Levels for Gas-Fired Pool Heaters

Efficiency Level	E_t (%)	Q_{PR} (Btu/h)	$Q_{off,r}$ (Btu/h)	PE (W)	$P_{W,SB}$ (W)**	$P_{W,OFF}$ (W)**	Integrated Thermal Efficiency (%)
EL 0	82	1,000	1,000	20	7.2	7.2	$TE_I = \frac{82(Q_{IN}+68)}{Q_{IN}+85{,}344}$
EL 1	82	0	0	20	7.2	7.2	$TE_I = \frac{82(Q_{IN}+68)}{Q_{IN}+2{,}113}$
EL 2	84	0	0	144	7.2	7.2	$TE_I = \frac{84(Q_{IN}+491)}{Q_{IN}+2{,}536}$
EL 3†	95	0	0	220	4.6	0	$TE_I = \frac{95(Q_{IN}+751)}{Q_{IN}+1{,}409}$

** Presented in terms of Btu/h in appendix P.
† The max-tech efficiency level includes standby and off mode technology options.

DOE research suggests that the standby electricity consumption, and the off mode electricity consumption are largely driven by the transformer, and is expected to be the same for all efficiency levels. DOE also does not expect the standby fuel energy consumption (pilot light consumption) to vary by capacity. DOE used these efficiency levels in the analysis as target efficiencies for calculating the incremental price of achieving increased efficiency. Figure 5.4.2 shows the integrated thermal efficiency equations from Table 5.4.3 across the entire available input capacity range.

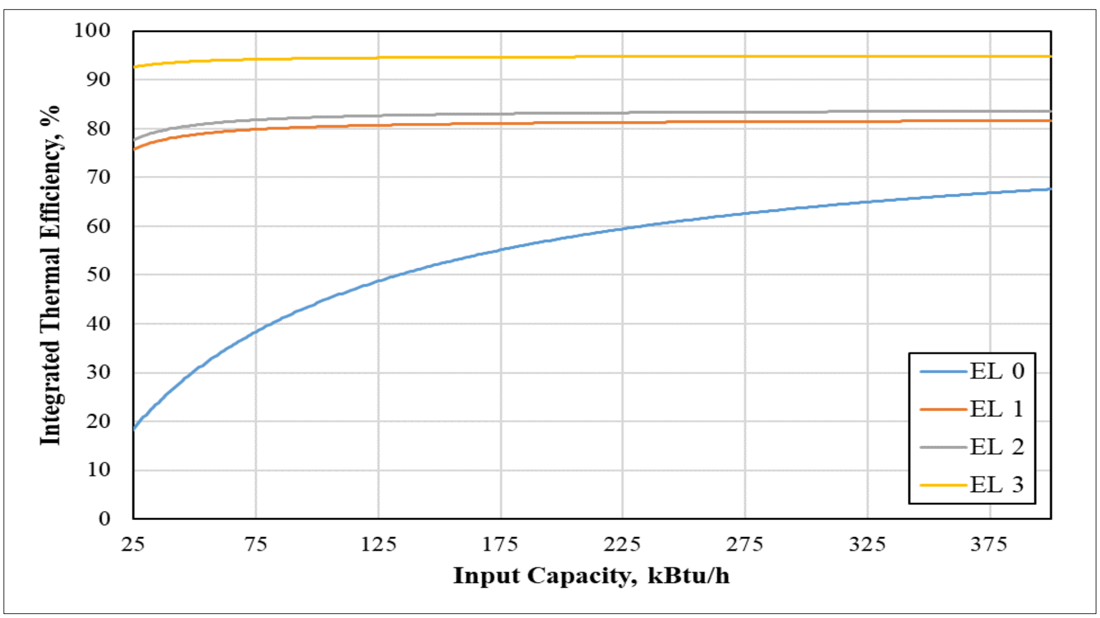

Figure 5.4.2 Efficiency Levels for Gas-Fired Pool Heaters

DOE notes that the design path shown above for the various efficiency levels include assumptions about the most likely way that manufacturers would typically meet that level. However, manufacturers have the flexibility to meet each efficiency level by making modifications to either their active or standby and off energy use and could decide to pursue other approaches than those shown in this analysis. These efficiency levels are meant to represent characteristics of/ models DOE found on the market as well as how those units would be tested according to the test procedure provisions related to standby and off mode.

5.4.3 "Max-Tech" Efficiency Levels

As part of its engineering analysis, DOE determined the maximum technologically feasible ("max-tech") improvement in energy efficiency for consumer pool heaters, as required by section 325(o) of EPCA. (42 U.S.C. 6295(o)). DOE surveyed the consumer pool heater market and found the max-tech level for gas-fired pool heaters by thermal efficiency. DOE then implemented standby and off mode technology options to the max-tech level. For electric pool heaters, DOE estimated the integrated thermal efficiencies using typical standby and off mode power consumption values and COP ratings. DOE determined that the max-tech efficiency level analyzed in the April 2022 NOPR was representative of the maximum efficiency available on the market across a full range of heating capacities. Thus, DOE maintained the previously analyzed max-tech levels in this final rule analysis.

The max-tech level for each product class is shown in Table 5.4.4.

Table 5.4.4 "Max-Tech" Efficiency Levels for Pool Heaters

Product Class	"Max-Tech" (TE_I)
Electric Pool Heaters	$TE_i = \frac{610\,PE}{PE + 448}$
Gas-Fired Pool Heaters	$TE_I = \frac{95(Q_{IN} + 751)}{Q_{IN} + 1{,}409}$

5.5 COST ANALYSIS METHODOLOGY

This section describes the analytical methodology used in the engineering analysis to determine the manufacturer production costs. The results of the engineering analysis are cost-efficiency curves for each representative product class.

DOE began the process by identifying consumer pool heaters available in the market including the energy efficiency levels currently available in the market. DOE also identified the technologies and features that are typically incorporated into products at the baseline level and various energy efficiency levels above the baseline.

Next, DOE selected products for the physical teardown analysis at or near the representative capacities. DOE gathered the information from the physical teardown analysis to create a BOMs using reverse engineering methods (see section 5.5.1). DOE then used the physical teardown analysis to identify the design pathways manufacturers are typically using to alter the capacity and efficiency of consumer pool heaters. DOE calculated the MPC for products spanning the full range of efficiencies from the baseline to the maximum technology available for each product class. DOE also identified each technology or combination of technologies, in each product that was responsible for improving the energy efficiency.

During the preparation of the cost-efficiency comparison and MPCs, DOE held interviews with manufacturers to gain insight into the consumer pool heater industry and requested comments on the engineering approach DOE used in the analysis (see section 5.5.4). DOE used the information gathered from these interviews to refine efficiency levels and technology pathways. Next, DOE converted the MPCs into MSPs (see section 5.6) using publicly available pool heating industry financial data, in addition to manufacturers' feedback.

5.5.1 Teardown Analysis

To assemble BOMs and calculate the manufacturing costs of the different components in consumer pool heaters, DOE disassembled multiple units into their components and estimated the material and labor cost of each individual component. This process is referred to as a "physical teardown." A supplementary method, called a "catalog teardown," uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a product that was physically disassembled and a similar product that was not. The teardown analysis for this engineering analysis included seven physical teardowns electric pool heaters and sixteen physical teardowns of gas-fired pool heaters.

5.5.1.1 Selection of Units

During the process of selecting units for teardowns, DOE considered three main questions:

- What efficiency levels should be captured in the teardown analysis?
- Are there units on the market that capture all potential efficiency levels?
- Which of the available units are most representative?

In responding to the preceding questions, DOE adopted the following criteria for selecting units for the teardown analysis:

- The selected products should span the full range of efficiency levels for each product class under consideration;
- The selected products should primarily come from manufacturers with large market share in that product class, although the highest efficiency products were chosen irrespective of manufacturer; and
- The selected products should have non-efficiency related features that are the same or similar to features of other products in the same class and for a range of efficiency levels.

DOE surveyed the consumer pool heater industry and identified products available to consumers and prototypes developed by manufacturers' research efforts. DOE then applied the aforementioned criteria for selecting models at the baseline efficiency levels, intermediate efficiency levels, and max-tech levels and selected products for the physical teardown that met the product description, the energy efficiency level, and included the technologies identified in the market surveys (see sections 5.4, 5.5.2).

Using the data gathered from the physical teardowns, DOE characterized each component according to its weight, dimensions, material, quantity, and the manufacturing processes used to fabricate and assemble it. For supplementary catalog teardowns, DOE gathered product data from publicly available manufacturer catalogs, such as dimensions, weight, and design features. DOE obtained information and data not typically found in catalogs and brochures, such as compressor specifications, or assembly details, from the physical teardowns of a similar product or by estimations based on industry knowledge. DOE collected additional component information during the engineering manufacturer interviews.

DOE selected seven electric and sixteen gas-fired pool heaters to represent the market, and used these for physical teardowns in the engineering analysis. DOE did not explicitly identify the model number or manufacturer of the units it tore down because this could expose sensitive information about individual manufacturers' products.

5.5.1.2 Baseline Units

Electric resistance pool heaters, which were identified as the baseline design for electric pool heaters, are comprised of an outer case, electrical controls, heating elements within a vessel, a cold water inlet and a hot water outlet. An electric resistance pool heater creates heat by running an electrical current to a metal resistor which acts as a heating element. The pool water enters the pool heater and flows over the heating element and heat is transferred to the pool water.

DOE has determined the baseline gas-fired pool heater to be a unit that just meets the federal energy conservation standard of 82% thermal efficiency and utilizes a standing pilot ignition system. These units are typically atmospherically drafted.

The consumer pool heater baseline unit for each product class was a reference point for determining the cost-efficiency relationship of units with higher energy efficiencies. The design features incorporated into each baseline unit were compared to units with higher energy efficiencies to determine the change in manufacturing, installation, and operating costs (see chapter 8 of this TSD).

5.5.2 Technology Options

Technology options are technology and design changes manufacturers use to improve product energy efficiency. These technologies provide different ways to increase product energy efficiency from the minimum (baseline) to the maximum (max-tech) found on the market. While DOE recognizes that manufacturers use many different technologies and approaches to increase the energy efficiency of consumer pool heaters, the presented technologies and combination of technologies and their ordering is one possible way manufacturers could reach max-tech.

For the engineering analysis, DOE calculated the manufacturing costs for each efficiency level between the baseline and max-tech at each of the levels specified in section 5.4. Using the teardown analysis and discussions with manufacturers, DOE identified each technology incorporated into each efficiency level (*i.e.*, integrated thermal efficiency), and calculated the individual cost for each efficiency level (*i.e.,* MPCs, including the costs for the baseline unit and each incremental efficiency level). DOE averaged the costs to normalize the data and prevent exposing sensitive information about individual manufacturers' products. Once the MPC of each efficiency level was determined, DOE calculated the cost-efficiency curves (see section 5.7).

Technologies for improving energy efficiency of consumer pool heaters were identified in the market and technology assessment (see chapter 3 of this TSD) and then subjected to the screening criteria (see chapter 4 of this TSD). The technologies that met the criteria of the screening analysis were considered as viable technologies for improving energy efficiency in the engineering analysis; however, the engineering analysis reflects the inclusion of what DOE expects to be the most likely technology(ies) to meet a given efficiency level. Information gathered from the teardown analysis, manufacturer interviews, and information gathered from publicly available product literature was used to determine which technologies manufacturers incorporate into products that are currently available to consumers at various efficiency levels, which DOE expects would be the technologies most likely to be used to meet amended standards. For example, DOE determined that standby mode and off mode power saving technology options would generally not be implemented by manufacturers until after improvements to heat exchangers were first implemented due to the engineering considerations that would be involved in these electrical upgrades. DOE also determined which technologies manufacturers are most likely to include in future products. Although several technologies are not included in the engineering analysis because they are not typically included in existing products (usually due to cost-related concerns) DOE acknowledges that these are still viable methods to improve the energy efficiency of consumer pool heaters.

Table 5.5.1 and Table 5.5.2 list the technologies that DOE included in the engineering analysis for electric pool heaters and gas-fired pool heaters, respectively.

Table 5.5.1 Technologies Considered in the Engineering Analysis for Electric Pool Heaters

Technology
R-410A Heat Pump: condenser with twisted Titanium tube coil in concentric/counter flow PVC pipe
R-410A Heat Pump: increased evaporator surface area
R-410A Heat Pump: increased condenser surface area (length of Titanium tube coil)
Seasonal Off Switch
Switch Mode Power Supply

Table 5.5.2 Technologies Considered in the Engineering Analysis for Gas-Fired Pool Heaters

Technology
Electronic Ignition
Improved Heat Exchanger
Condensing
Seasonal Off Switch
Switch Mode Power Supply

Commonly used technologies for each baseline, intermediate, and max-tech efficiency level are described in Table 5.5.3 for electric pool heaters and Table 5.5.4 for gas-fired pool heaters.

Table 5.5.3 Electric Pool Heater Efficiency Levels and Technologies

Efficiency Level	Technology
EL 0	Electric Resistance
EL 1	Heat Pump, twisted Titanium tube coil in concentric/counter flow PVC Pipe
EL 2	EL1 + increased evaporator surface area
EL 3	EL2 + increased evaporator surface area
EL 4	EL3 + increased evaporator surface area
EL 5	EL4 + condenser coil length, seasonal off switch, switch mode power supply

Table 5.5.4 Gas-Fired Pool Heater Efficiency Levels and Technologies

Efficiency Level	Technology
EL 0	Standing Pilot, Cu or CuNi Finned Tube, Atmospheric
EL 1	Electronic Ignition, Cu or CuNi Finned Tube, Atmospheric
EL 2	Electronic Ignition, Cu or CuNi Finned Tube, Blower Driven Gas/Air Mix
EL 3	Condensing, CuNi and Cu finned tube, seasonal off switch, switch mode power supply

5.5.3 Cost Estimates

5.5.3.1 Generation of Bills of Materials

The end result of each teardown is a structured BOM. DOE developed structured BOMs for each of the physical and catalog teardowns. Structured BOMs describe each product part and its relationship to the other parts in the estimated order in which manufacturers assembled them. The BOMs describe each fabrication and assembly operation in detail, including the type of equipment needed (*e.g.*, presses, drills), the process cycle times, and the labor associated with each manufacturing step. The result is a thorough and explicit model of the production process, which includes space, conveyor, and equipment requirements by planned production level.

The BOMs incorporate all materials, components, and fasteners classified as either raw materials or purchased parts and assemblies. The classifications into raw materials or purchased parts were based on DOE's previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEM). DOE also visited manufacturing plants to reinforce its understanding of the industry's current manufacturing practices for each of the product classes.

For purchased parts, the purchase price is estimated based on volume-variable price quotations and detailed discussions with manufacturers. For fabricated parts, the prices of "raw" materials (*e.g.*, tube, sheet metal) are estimated on the basis of 5-year averages. The cost of transforming the intermediate materials into finished parts is estimated based on current industry pricing. DOE shared major estimates with manufacturers during the manufacturer interviews to gain feedback on the analysis, its methodology, and results.

5.5.3.2 Cost Structure of the Spreadsheet Models

The manufacturing cost assessment methodology used is a detailed, component-focused technique for calculating the manufacturing cost of a product (direct materials, direct labor, and the overhead costs associated with production). The first step in the manufacturing cost assessment was the creation of a complete and structured BOM from the disassembly of the units selected for teardown. The units were dismantled, and each part was characterized according to weight, manufacturing processes used, dimensions, material, and quantity. The BOM incorporates all materials, components, and fasters with estimates of raw material costs and purchased part costs. Assumptions on the sourcing of parts and in-house fabrication were based on industry experience and discussions with manufacturers. Interviews and plant visits were conducted with manufacturers to add industry experience on the methodology and pricing.

The last step was to convert this information into dollar values. To perform this task, DOE collected information on labor rates, tooling costs, raw material prices, and other factors. DOE assumed values for these parameters using internal expertise and confidential information available to DOE contractors. Although most of the assumptions are manufacturer specific and cannot be revealed, section 5.5.3.4 provides a discussion of the values used for each assumption.

In summary, DOE assigned costs of labor, materials, and overhead to each part whether purchased or produced in-house. DOE then aggregated single-part costs into major assemblies (*e.g.*, outdoor fan assembly, heat exchanger assembly, controls, etc.) and summarized these costs in a worksheet. During confidential interviews with manufacturers, DOE showed key cost estimates and asked for feedback. DOE considered any information manufacturers gave and incorporated it into the analysis, if appropriate.

5.5.3.3 Definitions

Once DOE disassembled selected units, gathered information from manufacturer catalogs on additional products, and identified technologies, DOE performed a manufacturing cost analysis that could translate physical information into MPCs. The cost analysis is based on production activities and divides factory costs into the following categories:

- Materials: Purchased parts (*i.e.* fan assembly.), raw materials (*i.e.*, PVC, copper tube, etc.), and indirect materials that are used for processing and fabrication.
- Labor: Fabrication, assembly, indirect, and supervisor labor. Fabrication and assembly labor cost are burdened with benefits and supervisory costs.
- Overhead: Equipment, tooling, and building depreciation, as well as utilities, equipment and tooling maintenance, insurance, and property taxes.

Because there are many different accounting systems and methods to monitor costs, DOE defined the above terms as follows:

- Direct material: Purchased parts (out-sourced) plus manufactured parts (made in-house from raw materials).
- Indirect material: Material used during manufacturing (*e.g.*, welding rods, adhesives).
- Fabrication labor: Labor associated with in-house piece manufacturing.
- Assembly labor: Labor associated with final assembly.
- Indirect labor: Labor costs that scaled with fabrication and assembly labor. This included the cost of technicians, manufacturing engineering support, stocking, etc. that were assigned on a span basis.
- Equipment and plant depreciation: Money allocated to pay for initial equipment installation and replacement as the production equipment wears out.
- Tooling depreciation: Cost for initial tooling (including non-recurring engineering and debugging of the tools) and tooling replacement as it wears out.
- Building depreciation: Money allocated to pay for the building space and the conveyors that feed and/or make up the assembly line.
- Utilities: Electricity, gas, telephones, etc.
- Maintenance: Annual money spent on maintaining tooling and equipment.
- Insurance: Appropriated as a function of unit cost.
- Property Tax: Appropriated as a function as unit cost.

5.5.3.4 Assumptions Overview

As discussed in the previous section, assumptions about manufacturer practices and cost structure played an important role in estimating the final product cost. Some assumptions were different for specific manufacturers, depending on their market position, manufacturing practices, and size.

In converting physical information about the product into cost information, DOE reconstructed manufacturing processes for each component using internal expertise and knowledge of the methods used by the industry. DOE used assumptions regarding the manufacturing process parameters (*e.g.*, equipment use, labor rates, tooling depreciation, and cost of purchased raw materials) to determine the value of each component. DOE then summed the values of the components into assembly costs and, finally, the total product cost. The product cost included the material, labor, and overhead costs associated with the manufacturing facility. The material costs included both direct and indirect materials. The labor costs included fabrication, assembly, indirect, direct, and supervisor labor rates, including the associated overhead.

The labor costs were determined by the type of consumer pool heater manufactured at the factory. Overhead costs included equipment depreciation, tooling depreciation, building depreciation, utilities, equipment, tooling maintenance, insurance, property, and taxes.

DOE presented an initial draft of the cost-efficiency curve to manufacturers during the interviews. Using the information gathered from the interviews, DOE made updates to the analysis to address manufacturer comments. These changes involved updating component and material pricing, and production volumes. DOE utilized a continuous refinement process to update information. Changes to the analysis were made immediately after interviews so that refined data could be presented to the next manufacturer. Positive feedback from manufacturers presented with refined data confirmed the accuracy of the changes.

The next sections discuss specific assumptions about outsourcing, factory parameters, production volumes, and material prices. When the assumptions are manufacturer-specific, they are presented as industry averages to prevent disclosure of confidential information.

Fabrication Estimates

DOE characterized parts based on whether manufacturers purchased them from outside suppliers or fabricated them in-house. For purchased parts, DOE estimated the purchase price. For fabricated parts, DOE estimated the price of raw materials (*e.g.*, tube, sheet metal) and the cost of transforming them into finished parts. Whenever possible, DOE obtained price quotes directly from the manufacturers' suppliers.

DOE based the manufacturing operations assumptions on internal expertise, interviews with manufacturers, and manufacturing facilities site visits. The major manufacturer processes identified and developed for the spreadsheet model are listed in Table 5.5.5.

Table 5.5.5 In-House Manufacturing Operation Assumptions

Fabrication	Finishing	Assembly/Joining	Quality Control
Fixturing	Washing	Adhesive Bonding	Inspecting and Testing
Stamping/Pressing	Painting	Spot Welding	
Turret Punch	Powder Coating	Seam Welding	
Tube Forming	De-burring	Packaging	
Brake Forming	Polishing		
Cutting and Shearing	Refrigerant Charging		
Insulating/Insulation Injection			

Fabrication process cycle times were estimated and entered into the BOM. Electric resistance pool heaters, heat pump pool heaters, and gas-fired pool heaters have different manufacturing processes. These differences are reflected in the purchased components.

Production Volumes Assumptions

A manufacturer's production volumes vary depending on several factors, including market share. DOE based production volume assumptions for consumer pool heaters on industry knowledge and manufacturer interviews.

Manufacturers of consumer pool heaters serve a small market segment and are considered "luxury" items (*i.e.*, unlike water heaters which are considered a household necessity). Additionally, shipment levels fluctuate and are dependent upon the time of year, consumer preferences, economic conditions, and changing regulations from local governments. Five manufacturers supply the majority of electric pool heaters to the U.S. market. Based on information provided by manufacturers, DOE estimated that a representative shipment volume for a manufacturer of electric pool heaters is 8,000 units per year. Three manufacturers supply the majority of gas-fired pool heaters to the U.S. market. Based on information provided by manufacturers, DOE estimated that a representative shipment volume for a manufacturer of gas-fired pool heaters is 40,000 units per year.

Factory Parameters Assumptions

DOE used information gathered from publicly available literature, manufacturer interviews, and analysis of common industry practices to formulate factory parameters for consumer pool heater manufacturers. DOE first made assumptions about a set of factory parameters before the manufacturer interviews. DOE then revised the assumptions using comments and information gathered during the interviews.

Table 5.5.6 and Table 5.5.7 list DOE's assumptions for manufacturers of electric and gas-fired pool heaters, respectively.

Table 5.5.6 Electric Pool Heater Factory Parameter Assumptions

Parameter	Estimate
Plant Capacity (units/year)	10,000
Annual Production Volume (units/year)	8,000
Labor Wages ($/hr)	17.60
Fringe Benefits Ratio	75%

Table 5.5.7 Gas-Fired Pool Heater Factory Parameter Assumptions

Parameter	Estimate
Plant Capacity (units/year)	50,000
Annual Production Volume (units/year)	40,000
Labor Wages ($/hr)	16.00
Fringe Benefits Ratio	50%

Material Prices Assumptions

Common metals used in the fabrication of consumer pool heaters include aluminized cold rolled steel, and copper tubing. For parts fabricated in-house, the prices of the underlying "raw" metals (*e.g.*, tube, sheet metal) are estimated on the basis of 5-year averages to smooth out spikes in demand. Other "raw" materials such as plastic resins, insulation materials, etc. are estimated on a current-market basis.

The costs of raw materials are based on manufacturer interviews, quotes from suppliers, and secondary research. Past results are updated periodically and/or inflated to present-day prices using indices from resources such as MEPS Intl.[b], PolymerUpdate[c], the U.S. Geologic Survey (USGS)[d], and the Bureau of Labor Statistics (BLS)[e].

DOE used the BLS Producer Price Indices (PPIs) for copper rolling, drawing, and extruding and steel mill products, and made the adjustments to 2021$ using the gross domestic product implicit price deflator.[3] Table 5.5.8 shows the 5-year average metal prices DOE used for the analysis, in terms of 2022$.

Table 5.5.8 Metal Raw Material Cost, as of 06/2022

Metals	Five Year Cost Avg. (2022$/lb 07/2017-06/2022)	Cost As of 06/2022 (2022$/lb)
Cold Rolled Steel (CRS)	$0.59	$0.82
Aluminized CRS	$0.73	$1.01
Galvanized CRS	$0.73	$1.00
Pre-Painted CRS	$0.84	$1.17
Plain Cu Tube, ≤0.75" OD	$3.29	$4.10
Plain Cu Tube, >0.75" OD	$3.34	$4.16
Seamless Titanium Tube	$26.54	$28.60
Aluminum Fin Stock	$1.64	$1.98

5.5.4 Manufacturer Interviews

Throughout the rulemaking process, DOE seeks feedback and insight from interested parties to improve the information used in the analyses. For the engineering analysis, DOE discussed the analysis assumptions and estimates and cost-efficiency curves with various manufacturers of consumer pool heaters. DOE considered all the information manufacturers provided when refining the cost analysis. DOE incorporated equipment and manufacturing process figures into the analysis in the form of averages to avoid disclosing sensitive information about individual manufacturers' products or manufacturing processes.

DOE conducted an additional round of interviews after the publication of the April 2022 NOPR. These interviews solicited, in part, additional information on manufacturing production costs and design options, and this information was used to inform the final rule engineering analysis.

[b] For more information on MEPS Intl, please visit: https://www.meps.co.uk/
[c] For more information on PolymerUpdate, please visit: www.polymerupdate.com
[d] For more information on the USGS metal price statistics, please visit https://www.usgs.gov/centers/nmic/commodity-statistics-and-information
[e] For more information on the BLS producer price indices, please visit: https://www.bls.gov/ppi/

5.6 MANUFACTURER SELLING PRICE

The output of the cost analysis is the MPC, which includes all direct costs including production-related labor, materials, depreciation, and overhead costs (as defined in section 5.8). To obtain the MSP, DOE multiplies the MPC by the manufacturer markup and adds the cost of shipping. The MSP includes all production and non-production costs as well as profit. The manufacturer markup is a multiplier that scales MPC to the MSP and covers non-production cost elements, including sales, general and administrative, research and development, other corporate expenses, and profit. The components of MSP are shown in Figure 5.6.1. The MPCs are obtained as an output of the cost analysis, and the manufacturer markup and shipping costs were derived as described in sections 5.6.1 and 5.6.2 below.

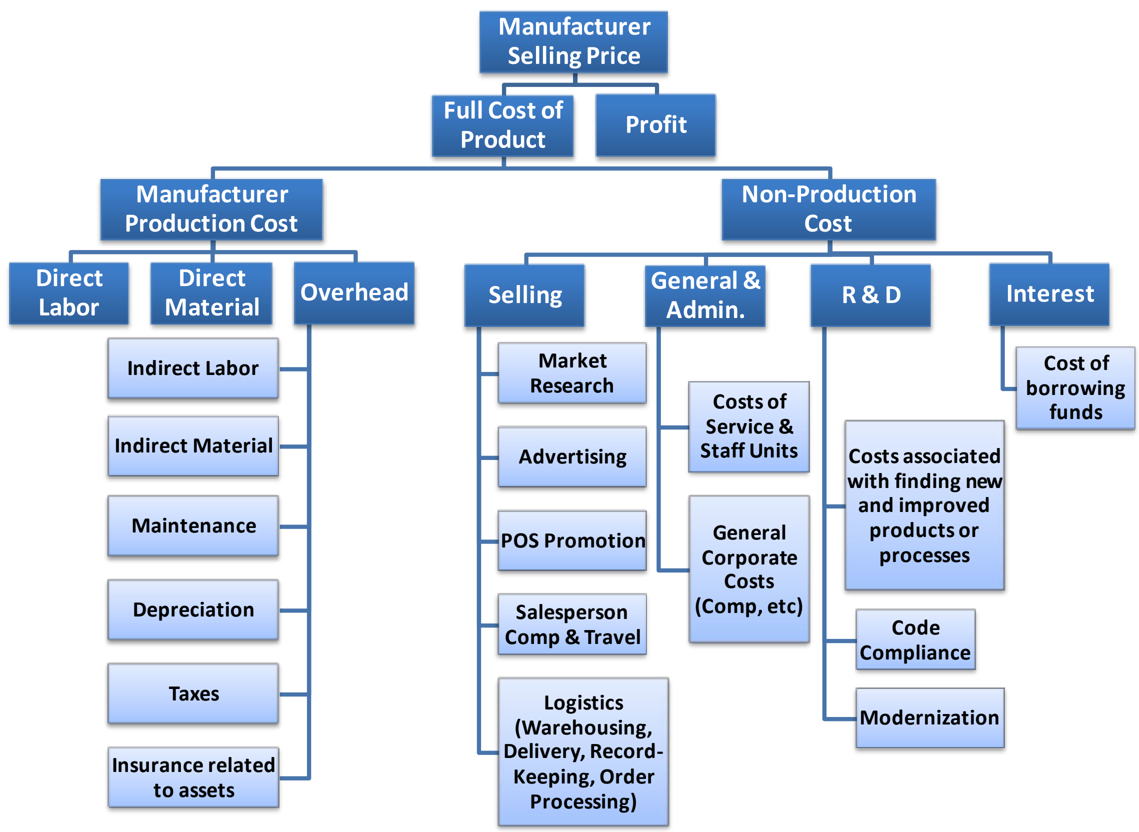

Figure 5.6.1 Breakdown of Manufacturer Selling Price

5.6.1 Manufacturer Markup

DOE used U.S. Security and Exchange Commission (SEC) 10-K reports from publicly owned consumer pool heater manufactures to estimate manufacturer markups. The law requires publicly owned companies to disclose financial information on a regular basis by filing forms with the SEC. The SEC form 10-K, filed by companies annually, provides a comprehensive overview of the company's business and financial conditions. The 10-K report includes the company's revenues and direct and indirect costs. The income statement section of the 10-K often lists the figures necessary for calculating the manufacturer markup—the net sales, costs of sales, and gross profit. DOE first calculated a five year average markup for each company. After calculating the markup for each manufacturer with 10-K data, DOE then calculated a single market-share weighted manufacturer markup to represent the industry. DOE applied this manufacturer markup to the MPC to arrive at a final manufacturer selling price. This industry wide markup was further calibrated based on feedback received during manufacturer interviews, and for the final rule DOE recalibrated the markups based on information gathered during interviews that were conducted after the NOPR stage. Based on the information received during these additional interviews, DOE revised its manufacturer markups estimates to 1.39 for electric pool heaters and 1.44 for gas-fired pool heaters for the final rule. See chapter 12 of this TSD for additional details.

5.6.2 Shipping Costs

Manufacturers of consumer pool heaters typically pay for freight to the first step in the distribution chain. Freight is not a manufacturing cost, but because it is a substantial cost incurred by the manufacturer, DOE is accounting for shipping costs separately from the non-production costs that comprise the manufacturer markup. To calculate MSP, DOE multiplied the MPC determined from the cost analysis by the manufacturer markup and added shipping costs. DOE calculated shipping costs based on a typical 40-foot straight frame trailer with a storage volume of 2,398 cubic feet and maximum weight capacity of 33,700 lbs.

DOE first calculated the cost per cubic foot of space on a trailer based on a cost of $5,753 per shipping load (from the Midwest of the United States to the coast) and the standard dimensions of a 40-foot trailer. This cost was determined based on a combination of full truck load (FTL) freight quotations and manufacturer feedback. Then, DOE examined the average sizes of products in each product class at each efficiency and capacity combination analyzed. DOE estimated the shipping costs by determining the maximum number of units that could fit on a trailer both by weight and storage volume (taking unit orientation into account) and using the smaller of the two numbers as the shipment volume per trailer. The shipping cost per unit was then found by dividing the number of units per trailer by the total trailer cost.

Table 5.6.1 and Table 5.6.2 show the shipping costs for electric and gas-fired pool heaters at each efficiency level, respectively. For electric pool heaters, the increase in shipping cost from EL 0 to EL 1 is due to the technology change from electric resistance to heat pump heating. A heat pump pool heater is about 13 times larger than an electric resistance pool heater due to the additional heat pump components. For gas-fired pool heaters there is no significant change in shipping costs.

Table 5.6.1 Shipping Costs for Electric Pool Heaters

Efficiency Level	Shipping Costs (2021$)
EL 0	11.96
EL 1	110.64
EL 2	110.64
EL 3	110.64
EL 4	110.64
EL 5	110.64

Table 5.6.2 Shipment Costs for Gas-Fired Pool Heaters

Efficiency Level	Shipping Costs (2021$)
EL 0	59.93
EL 1	59.93
EL 2	49.17
EL 3	73.76

5.6.3 MSP in the Downstream Analysis

The MSPs derived in the engineering analysis are important inputs to the LCC and MIA analyses. In the LCC, the MSPs are necessary to calculate the total installed cost of each unit. In the MIA, DOE constructs a number of scenarios that analyze how different pricing schemes impact manufacturers financially. In the MIA, both MSP and the direct production cost components of MSP are important drivers of results. DOE discusses how the engineering analysis is used in the other analyses in chapters 8 and 12 of this TSD.

5.7 COST VERSUS EFFICIENCY CURVES

DOE first estimated the MPC of the baseline units for consumer pool heaters. DOE then determined the intermediate efficiency levels up to the max-tech level (described by integrated thermal efficiency) that represent the consumer pool heater market. Additionally, DOE identified the MPCs for each of these intermediate efficiency levels.

DOE created cost curves for electric pool heaters and gas-fired pool heaters as shown in Figure 5.7.1 and Figure 5.7.2, respectively.

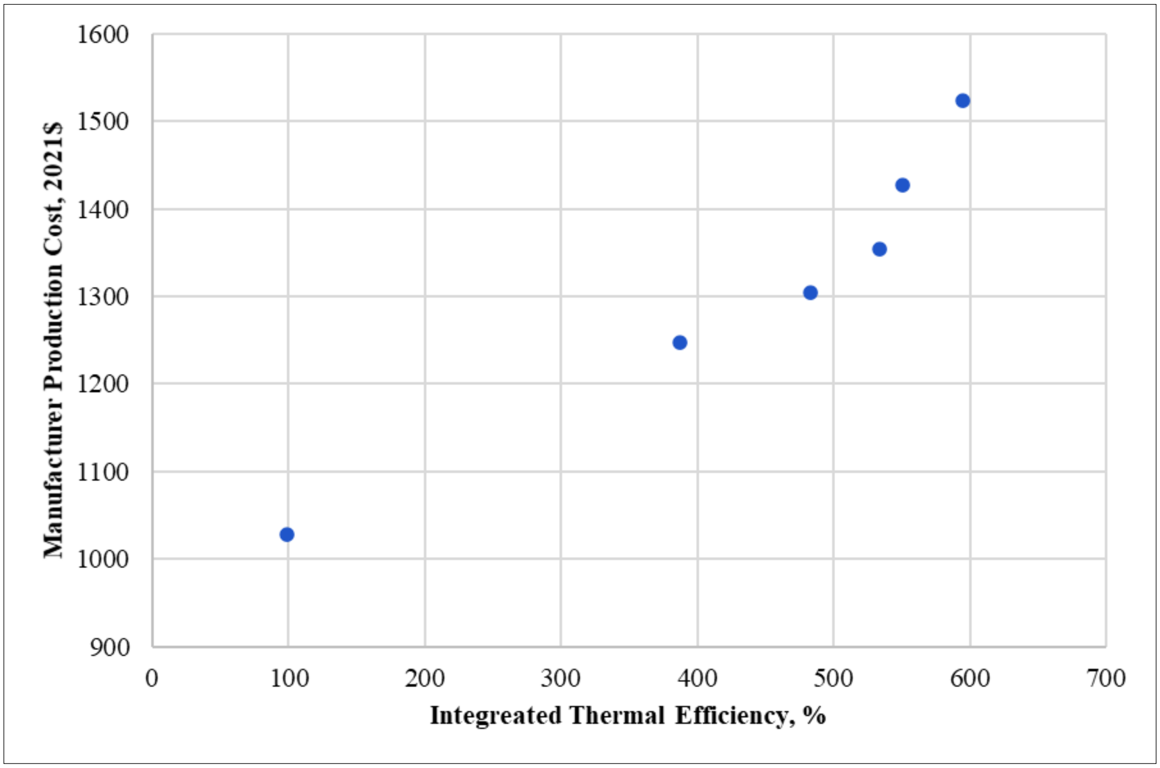

Figure 5.7.1 Manufacturer Production Cost (2021$) versus Integrated Thermal Efficiency for Electric Pool Heater, 110,000 Btu/h

The results show that the cost-efficiency curves are nonlinear. Generally, as the efficiency increases, manufacturing becomes more difficult and more costly for manufacturers. The MPC increases greatly when heat pump technology is used as an alternative to resistive heating (from baseline to EL1). Compared to the cost-efficiency curves analyzed in the April 2022 NOPR, these curves demonstrate a significant increase in material prices, which generally agrees with feedback DOE received in public comments and in confidential manufacturer interviews.

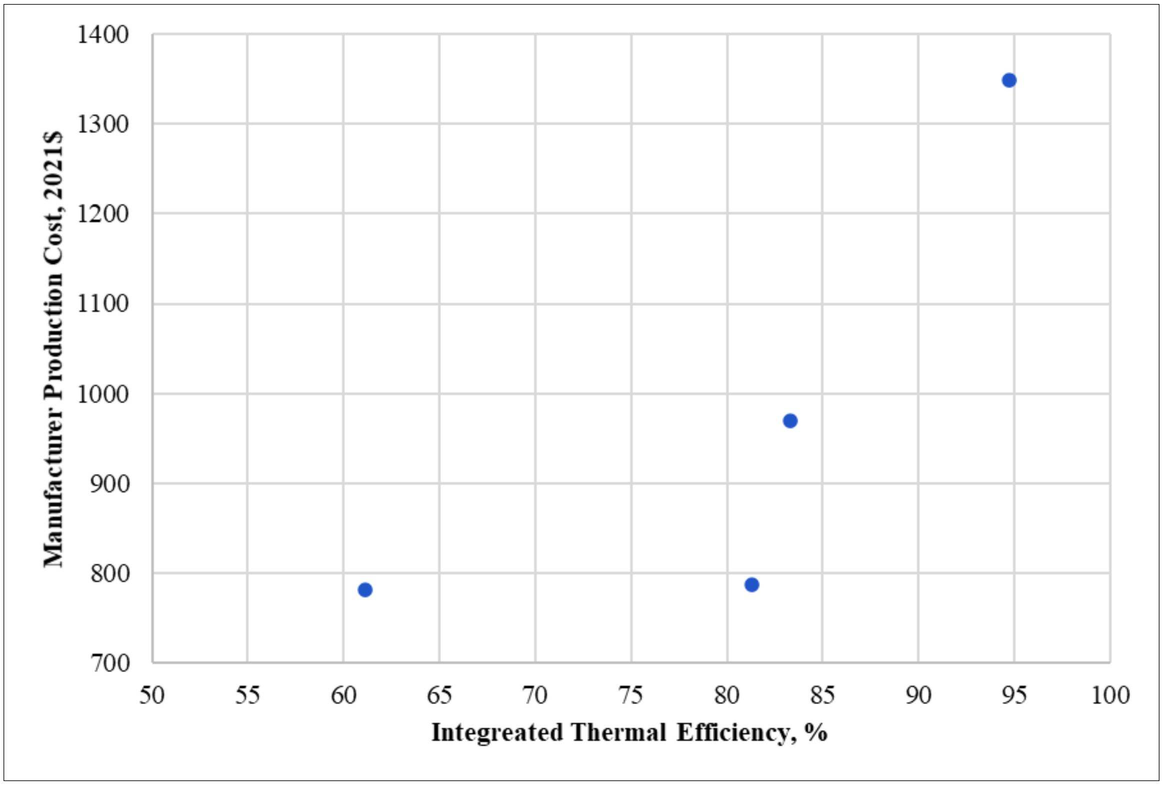

Figure 5.7.2 Manufacturer Production Cost (2021$) versus Integrated Thermal Efficiency for Gas-Fired Pool Heater, 250,000 Btu/h

The results show that the cost-efficiency curves are nonlinear. Generally, as the efficiency increases, manufacturing becomes more difficult and more costly for manufacturers. The MPC increases slightly and the integrated thermal efficiency increases greatly when electronic ignition is used as an alternative to a standing pilot (from baseline to EL1). The MPC and integrated thermal efficiency both increase significantly when condensing technology is used (EL3). Compared to the cost-efficiency curves analyzed in the April 2022 NOPR, these curves demonstrate a significant increase in material prices, which generally agrees with feedback DOE received in public comments and in confidential manufacturer interviews.

5.8 MPC BREAKDOWN

After DOE incorporated all of the assumptions into the cost analysis, the different production costs percentages were calculated. DOE calculated the average product costs percentages for consumer pool heaters. Table 5.8.1 shows the different percentages for the production costs that make up the total product MPC. DOE notes that although electric resistance pool heaters and heat pump pool heaters are both covered under the electric pool heater product class, their MPC breakdowns differ and are therefore shown separately in the table below.

Table 5.8.1 Total Product MPC Breakdown for Consumer Pool Heaters

	Percentage Cost Breakdown		
	Electric Resistance (Baseline)	**Heat Pump (Average EL 1 – Max-Tech)**	**Gas-Fired (Average EL 0 – Max-Tech)**
Materials	79%	91%	78%
Labor	9%	5%	11%
Depreciation	6%	1%	6%
Overhead	6%	2%	5%

5.9 ENGINEERING ANALYSIS SUMMARY OF RESULTS

The MPCs and MSPs of the representative electric and gas-fired pool heaters at each efficiency level analyzed are shown in Table 5.9.1 and Table 5.9.2, respectively.

Table 5.9.1 MPC and MSP for Electric Pool Heaters, 110,000 Btu/h Output Capacity

Efficiency Level	MPC (2021$)	MSP (2021$)
EL 0	1,028	1,441
EL 1	1,248	1,845
EL 2	1,305	1,924
EL 3	1,355	1,993
EL 4	1,427	2,094
EL 5	1,523	2,228

Table 5.9.2 MPC and MSP for Gas-Fired Pool Heaters, 250,000 Btu/h Output Capacity

Efficiency Level	MPC (2021$)	MSP (2021$)
EL 0	782	1,186
EL 1	788	1,195
EL 2	969	1,445
EL 3	1,349	2,016

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CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

To carry out its analyses, the U.S. Department of Energy (DOE) develops appropriate markups (*e.g.*, manufacturer markups, wholesaler markups, retailer markups, contractor markups, builder markups) in the distribution chain and sales taxes to convert manufacturer production cost (MPC) estimates derived in the engineering analysis to consumer prices, which are then used in the life-cycle cost (LCC) and payback period (PBP) analysis.

DOE develops markups for each market participant in the various distribution channels for electric pool heaters (EPHs) and gas-fired pool heaters (GPHs). Generally, companies mark up the price of a product to cover their business costs and profit margin. In financial statements, gross margin (GM) is the difference between the company revenue and the company cost of sales or cost of goods sold (CGS). The GM takes account of the expenses of companies in the distribution channel, including overhead costs (sales, general, and administration); research and development (R&D); interest expenses; depreciation; and taxes—and company profits. To cover costs and to contribute positively to company cash flow, the price of products must include a markup. Products command lower or higher markups depending on company expenses associated with the product and the degree of market competition.

DOE estimated a baseline markup and an incremental markup for each market participant besides manufacturers. DOE defined a baseline markup as a multiplier that converts the manufacturer selling price (MSP) of products with baseline efficiency to the consumer purchase price. An incremental markup is defined as the multiplier to convert the incremental increase in MSP of higher efficiency products to the consumer purchase price. Because companies mark up the price at each point in the distribution channel, both baseline and incremental markups are dependent on the distribution channel, as described in section 6.2.

6.2 DISTRIBUTION CHANNELS

The appropriate markups for determining consumer product prices depend on the type of distribution channels through which products move from manufacturers to purchasers.

The majority of EPHs and GPHs are purchased for residential use, but a small fraction of them are purchased to be installed in small to mid-size commercial buildings. DOE estimated that 94 percent of EPH and 87 percent of GPH shipments are for residential applications and the rest go to commercial applications. Hence, DOE calculated the markups separately for residential and commercial applications for both EPHs and GPHs.

DOE modeled two primary markets describing the way most products pass from the manufacturer to the consumer. The first type of market applies to pool heater replacements or new owners of pool heaters with an existing swimming pool, and the second type of market applies to new swimming pool construction. DOE estimated the fraction of pool heater shipments installed in the replacement or new owner market is 64 percent for EPHs and 58 percent for GPHs in residential applications, while this fraction in commercial applications is 89 percent for EPHs and 88 percent for GPHs. The remaining pool heater shipments were assumed to be installed in the new construction market.

In the pool heater replacement and new owner market, the manufacturer generally sells the product to a wholesaler, who in turn sells it to either a pool contractor or pool retailer, who in turn sells it to the consumer. The pool heater wholesalers are the primary sales channel for both EPHs and GPHs, with PoolCorp being the leading wholesale company in the market. Pool contractors are responsible for installing and servicing pool heaters, and they generally purchase the products from pool heater wholesalers. In another similar but less common distribution channel, pool contractors purchase the product from buying groups who are able to negotiate price reductions from manufacturers through their collective purchasing power instead of from wholesalers. In some cases, consumers purchase the pool heaters from a pool specialty store who often subcontract a pool contractor or have a service branch with licensed pool contractors to install the products for pool owners. Many of those large pool specialty stores (*i.e.*, Leslie's Swimming Pool Supplies) also have direct purchase agreements with pool product manufacturers and thus serve as their own wholesalers. This type of direct retailer channel makes up a significant fraction of the pool heater retail market. According to inputs from 2022 Pkdata,[1] DOE used the following market breakdown for the aforementioned distribution channels under the pool heater replacement and new owner market in residential applications (Table 6.2.1). DOE welcomes information that could support improvement in characterizing the market structure of EPHs and GPHs.

Table 6.2.1 Market Shares for Distribution Channels in the Replacement and New Owner Market in Residential Applications

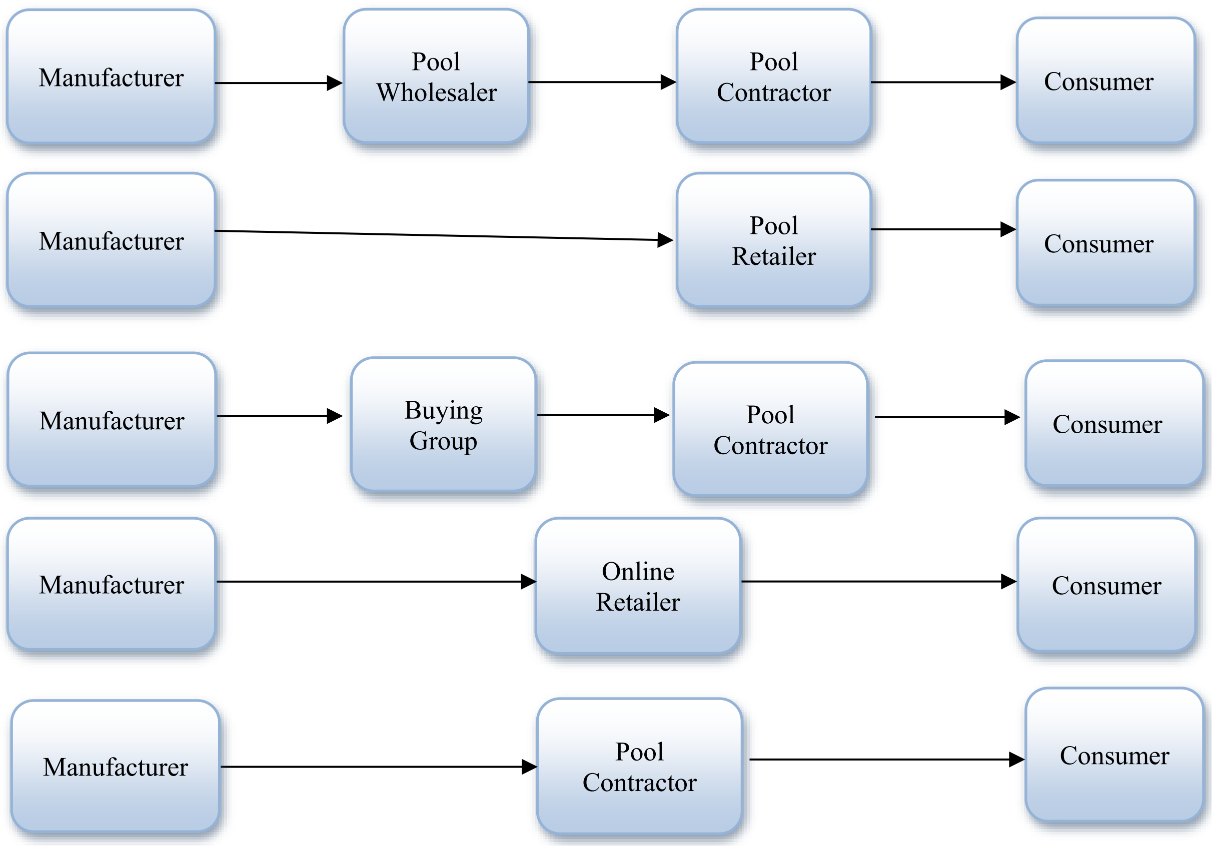
Distribution Channel	Market Share
Manufacturer → Pool Wholesaler → Pool Contractor → Consumer	45%
Manufacturer → Buying Group → Pool Contractor → Consumer	5%
Manufacturer → Pool Retailer → Consumer	25%
Manufacturer → Pool Contractor → Consumer	10%
Manufacturer → Online Retailer → Consumer	15%

In the new swimming pool construction market, most products could either be sold to a wholesaler or a buying group, who in turn sells them to a pool builder, who in turn sells them to the consumer. According to the comments provided during manufacturer interviews, it is estimated that around 45 percent of the new swimming pool construction market goes through a wholesalers to pool builders channel and another 45 percent goes through buying groups to pool builders channel (Table 6.2.2). The buying groups have the ability to leverage their collective purchasing power to negotiate price reductions from manufacturers; hence, DOE assumed the buying groups have markups that are half of the value of wholesaler's markups. DOE estimated that about 10 percent of the products could go directly from the manufacturer to pool builders. Figure 6.2.1 illustrates the six distribution channels for EPHs and GPHs in residential applications.

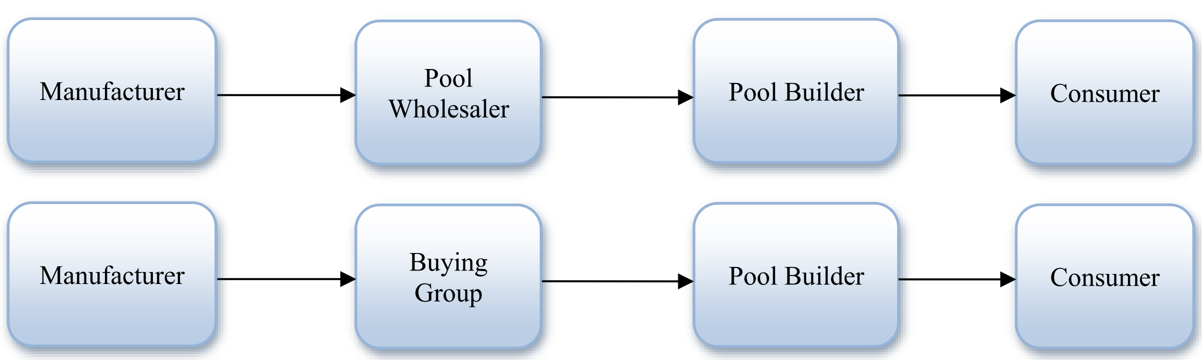
Table 6.2.2 Market Shares for Distribution Channels in the New Swimming Pool Construction Market in Residential Applications

Distribution Channel	Market Share
Manufacturer → Pool Wholesaler → Pool Builder → Consumer	45%
Manufacturer → Buying Group → Pool Builder → Consumer	45%
Manufacturer → Pool Builder → Consumer	10%

Pool Heater Replacement and New Owners:



New Swimming Pool Construction:



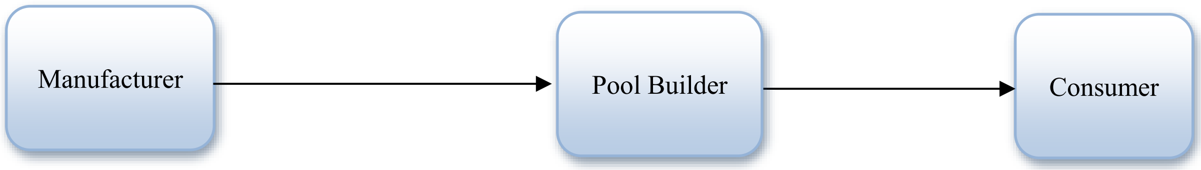


Figure 6.2.1 Distribution Channels for Electric Pool Heaters and Gas-fired Pool Heaters in Residential Applications

For EPHs and GPHs installed in commercial applications, DOE assumed that half of the market follow the similar distribution channels as in residential applications and the other half go through typical distribution channels as other heating, ventilation, and air conditioning (HVAC) equipment in commercial applications. DOE also considered a distribution channel for which the manufacturer sells the pool heaters to the wholesaler and then to the consumer through a national account under both replacement and new construction markets. This national account distribution channel is applicable to small to mid-size commercial buildings where the on-site staff or internal personnel generally purchase equipment from wholesalers at much lower prices due to the large volume purchased and perform the installation themselves. Occasionally, the equipment manufacturers and wholesalers can be the same entity, so the consumer selling price could potentially be even lower than the usual national account channel. However, DOE did not have sufficient information to determine the appropriate markup for this particular distribution channel.

Table 6.2.3 Market Shares for Distribution Channels in the Replacement and New Owner Market in Commercial Applications

Distribution Channel	Market Share
Manufacturer → Pool Wholesaler → Pool Contractor → Consumer	30%
Manufacturer → Buying Group → Pool Contractor → Consumer	10%
Manufacturer → Pool Contractor → Consumer	10%
Manufacturer → HVAC Wholesaler → HVAC Contractor → Consumer	40%
Manufacturer → HVAC Wholesaler → Consumer (National Account)	10%

Table 6.2.4 Market Shares for Distribution Channels in the New Swimming Pool Construction Market in Commercial Applications

Distribution Channel	Market Share
Manufacturer → Pool Wholesaler → Pool Builder → Consumer	30%
Manufacturer → Buying Group → Pool Builder → Consumer	10%
Manufacturer → Pool Builder → Consumer	10%
Manufacturer → HVAC Wholesaler → Pool Builder →HVAC Contractor → Consumer	40%
Manufacturer → HVAC Wholesaler → Consumer (National Account)	10%

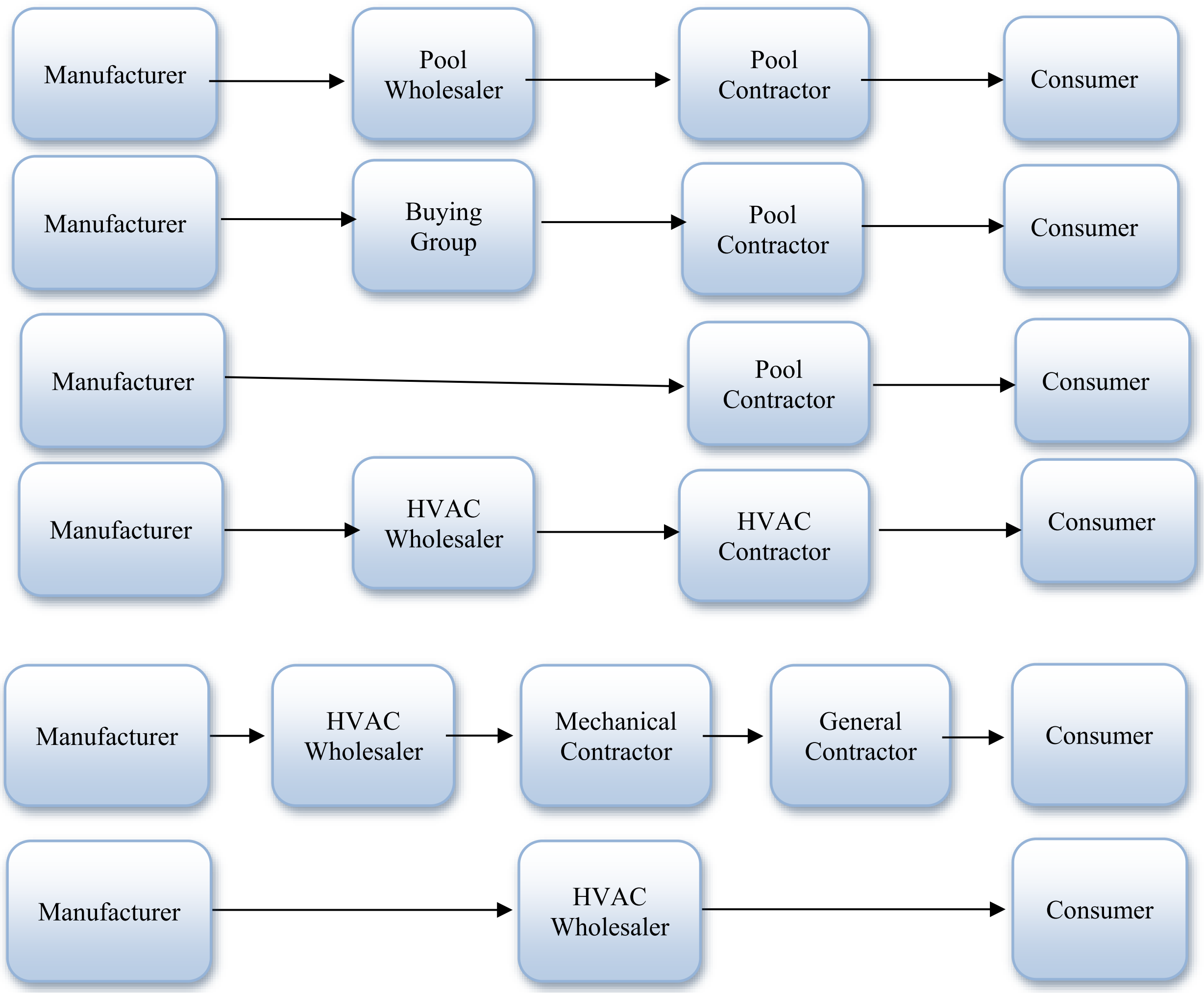


Figure 6.2.2 Distribution Channels for Electric Pool Heaters and Gas-fired Pool Heaters in Commercial Applications

Based on information provided from manufacturer interviews, there is another possible distribution channel where manufacturers sell the EPHs and GPHs to online retailers who in turn sell them directly to consumers and the consumer then installs the pool heater. This online distribution channel mainly applies to the do-it-yourself (DIY) installation which represents a negligible fraction of the market, considering the installation of pool heaters requires technical knowledge on electrical wiring that most of the consumers do not acquire. Therefore, DOE did not consider this DIY channel in this analysis.

6.3 APPROACH FOR MANUFACTURER MARKUP

DOE used manufacturer markups to transform a manufacturer's product cost into a manufacturer sales price. The methodology to derive manufacturer markups was described in the engineering analysis (chapter 5).

6.4 APPROACH FOR WHOLESALER, CONTRACTOR, RETAILER, AND BUILDER MARKUPS

A change in energy efficiency standards usually increases the manufacturer selling price that wholesalers pay, and in turn the wholesale price that pool contractors, pool retailer or pool builder would pay. In the past, DOE used the same markups as for baseline products to estimate the product price of more efficient product. Applying a fixed markup on higher manufacturer selling price would imply an increase in the dollar margin earned by wholesalers and contractors, and an increase in per-unit profit.

Based on microeconomic theory, the degree to which firms can pass along a cost increase depends on the level of market competition, as well as the market structure on both supply and demand side (*e.g.*, supply and demand elasticity). DOE examined industry data from IBISWorld and the results suggest that most of the industries relevant to heating equipment wholesalers and contractors are generally quite competitive (see appendix 6B).[2,3] Under relatively competitive markets, it may be tenable for pool heater wholesalers, contractors and builder to maintain a fixed markup for a short period of time after the input price increases, but the market competition should eventually force them to readjust their markups to reach a medium-term equilibrium of which per-unit profit is relatively unchanged before and after standards are implemented.

Thus, DOE concluded that applying fixed markups for both baseline products and higher-priced products meeting a standard is not viable in the medium to long term considering the competitive nature of the pool heater wholesale and contractor industry. DOE developed the incremental markup approach based on the widely accepted economic view that firms are not able to sustain a persistently higher dollar margin in a competitive market in the medium term. If the price of the product increases under standards, the only way to maintain the same dollar margin as before is for the markup (and percent gross margin) to decline.

To estimate the markup under standards, DOE derived an incremental markup that is applied to the incremental equipment costs of higher efficiency products. The overall markup on the products meeting standards is an average of the markup on the component of the cost that is equal to the baseline product and the markup on the incremental cost, weighted by the share of each in the total cost of the standards-compliant product.

DOE's incremental markup approach allowed the part of the cost that is thought to be affected by the standard to scale with the change in manufacturer price. The income statements DOE used to develop wholesaler and contractor markups itemize firm costs into a number of expense categories, including direct costs to purchase or install the equipment, operating labor and occupancy costs, and other operating costs and profit. Although pool heater wholesalers and contractors tend to handle multiple commodity lines, DOE contended that these aggregated data provide the most accurate indication of the expenses associated with pool heaters and the cost structure of distribution channel participants.

DOE used these income statements to divide firm costs between those that are not likely to scale with the manufacturer price of equipment (labor and occupancy expenses, or "invariant" costs) and those that are (operating expenses and profit, or "variant" costs). For example, when the manufacturer selling price of equipment increases, only a fraction of a wholesaler's expenses increase (operating expenses and profit), while the remainder can be expected to stay relatively constant (labor and occupancy expenses). If the unit price of an EPH or GPH increases by 20 percent under standards, it is unlikely that the cost of secretarial support in an administrative office or office rental expenses will increase proportionally.

See Appendix 6B for further evidence supporting the use of incremental markups in this analysis. The derivation of incremental markups for wholesalers, pool contractors, pool retailers and pool builders are described in the following sections.

6.4.1 Wholesaler Markups

6.4.1.1 Pool Wholesaler Markups in Residential and Commercial Applications

According to the market assessment analysis and inputs from manufacturers, PoolCorp comprises around half of the residential pool wholesale market and has a modest degree of market power. Hence, DOE assumed that the markup used by PoolCorp is representative of the markup for residential pool wholesale industry. PoolCorp is a publicly owned company, so it is required by law to disclose financial information on a regular basis by the U.S. Securities and Exchange Commission (SEC).[4] The annual 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. Using the above assumptions, DOE applied the following two equations to calculate baseline and incremental markups with the financial data available from 10-K reports:

$$MU_{BASE} = \frac{Net\ Sales}{Cost\ of\ Sales}$$

Eq. 6.1

Incremental markups are coefficients that relate the change in the MSP of more energy-efficient models, or those products that meet the requirements of new energy conservation standards, to the change in the wholesaler sales price. DOE assumed that expenses like labor and occupancy costs remain fixed and need not be covered in the incremental markup. Profit and other operating costs were assumed to be variant and to scale with MSP. The SEC 10-K reports did not typically separate labor and occupancy costs from overall expenses, so DOE assumed that these fixed costs are encompassed by "selling, distribution and administrative expenses."

DOE also assumed that "operating profit" (operating income) covers other operating costs and profit (*i.e,.* variant cost). Each company's incremental markup was calculated as:

$$MU_{INCR} = 1 + \frac{Operating\ Profit}{Cost\ of\ Sales}$$

Eq. 6.2

6.4.1.2 HVAC Wholesaler Markups in Commercial Applications

DOE developed baseline and incremental wholesaler markups using the firm income statement for hardware and plumbing and heating equipment and supplies merchant wholesale sector from the 2017 U.S. Census *Annual Wholesale Trade Report ("AWTR")*.[5] Baseline markups cover all the wholesaler's costs (both fixed and variable). DOE calculated the baseline markup for wholesalers using the following equation.

$$MU_{BASE} = \frac{CGS_{WHOLE} + GM_{WHOLE}}{CGS_{WHOLE}} = \frac{CGS_{WHOLE} + (IVC_{WHOLE} + VC_{WHOLE})}{CGS_{WHOLE}}$$

Eq. 6.3

Where:

MU_{BASE} = baseline wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold,
GM_{WHOLE} = wholesaler gross margin,
IVC_{WHOLE} = wholesaler invariant costs, and
VC_{WHOLE} = wholesaler variant costs.

Incremental markups are multipliers that relate the change in the MSP of products that meet the requirements of new efficiency standards to the change in the wholesaler sales price. Incremental markups cover only those costs that scale with a change in the MSP (*i.e.*, variant costs, *VC*). DOE calculated the incremental markup (MU_{INCR}) for wholesalers using the following equation:

$$MU_{INCR} = \frac{CGS_{WHOLE} + VC_{WHOLE}}{CGS_{WHOLE}}$$

Eq. 6.4

Where:

MU_{INCR} = incremental wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold, and
VC_{WHOLE}= wholesaler variant costs.

6.4.2 Pool Contractor, Mechanical Contractor, and General Contractor Markup

DOE developed baseline and incremental markups for pool contractor in residential applications and mechanical contractor in commercial applications using the industry-level income statement for *Plumbing, Heating and Air-Conditioning Contractors* (NAICS[a] 238220) sector from the 2017 U.S. Economic Census,[6] which is the most disaggregated sector that includes pool contracting business. DOE also collected financial data from Commercial Building Construction series (NAICS 236220)[7] to estimate national average markups for commercial general contractors. The baseline markups cover all of the pool contractor's costs (both *invariant costs* and *variant costs*). DOE calculated the baseline markup for all contractors using the following equation:

$$MU_{CONT\_BASE} = \frac{CGS_{CONT} + GM_{CONT}}{CGS_{CONT}} = \frac{CGS_{CONT} + (IVC_{CONT} + VC_{CONT})}{CGS_{CONT}}$$

Eq. 6.5

Where:

MU_{CONT_BASE} = baseline contractor markup,
CGS_{CONT} = contractor's cost of goods sold,
GM_{CONT} = contractor's gross margin,
IVC_{CONT} = contractor's invariant costs, and
VC_{CONT} = contractor's variant costs.

Analogously to wholesalers, DOE estimated the incremental pool contractor, mechanical contractor and commercial general contractor markups by only marking up those costs that scale with a change in the MSP (variant costs, *VC*) for more energy-efficient products. As above, DOE assumed a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses), and those that do (other operating expenses and profit). Hence, DOE categorized the Census data into each major cost category and estimated incremental markups using the following equation:

$$MU_{CONT\_INCR} = \frac{CGS_{CONT} + VC_{CONT}}{CGS_{CONT}}$$

Eq. 6.6

Where:

MU_{CONT_INCR} = incremental contractor markup,
CGS_{CONT} = contractor's cost of goods sold, and
VC_{CONT}= contractor's variant costs.

To differentiate mechanical contractor markups between replacement and new construction market in commercial applications, DOE relied on Air Conditioning Contractors of

[a] North American Industry Classification System (NAICS).

America (ACCA) 2005 Financial Analysis as it provides gross margin as percent of sales for replacement and new construction market separately.[8] Therefore, the baseline markup for both markets can be derived with the following equation:

$$MU_{BASE} = \frac{Sales(\%)}{Sales(\%) - GM(\%)}$$

Eq. 6.7

DOE then calculated the markup ratios of replacement and new construction market to all mechanical contractors derived from ACCA 2005 Financial Analysis and applied those ratios to the national average markup results from 2017 Economic Census to develop the baseline and incremental markups for replacement and new construction markets.

The markup results for all contractors can be found in section 6.5.3.

6.4.3 Pool Retailer Markup

DOE developed two retailer markups for pool heaters, one is to be applied to the wholesaler to pool retailer distribution channel and the other is for the direct retail sales channel. For the wholesaler to pool retailer distribution channel, DOE used the same methodology described in section 6.4.1.1 to estimate weighted-average retailer markups applied in this channel based on annual 10-K reports for major mass merchants, membership clubs, and home improvement centers. For the direct retail sales, DOE estimated the overall markups for pool retailer based on industry-level financial data for the *Miscellaneous Store Retailers* (NAICS 453) sector from the U.S. Census Bureau's 2017 Annual Retail Trade Survey (ARTS)[9], which is the most recent survey available with detailed operating expenses for this particular sector and the annual 10-K reports for Leslie's Swimming Pool Supplies, one of the major large pool specialty stores in the U.S.. DOE organized the financial data into statements that break down cost components incurred by firms in this category. DOE assumed that the income statements faithfully represent the various average costs incurred by firms selling EPHs and GPHs. Although pool retailers handle multiple commodity lines, the data provide the most accurate available indication of expenses for selling EPHs and GPHs.

The 2017 ARTS data contains total sales, gross margin and detailed operating expenses. DOE calculated the baseline markup (MU_{RET_BASE}) for pool retailers as an average markup using the following equation:

$$MU_{RET\_BASE} = \frac{CGS_{RET} + GM_{RET}}{CGS_{RET}}$$

Eq. 6.8

Where:

MU_{RET_BASE} = baseline pool retailer markup,
CGS_{RET} = pool retailer's cost of goods sold, and
GM_{RET}= pool retailer's gross margin.

Incremental markups cover only those costs that scale with a change in CGS (variant costs, *VC*). DOE calculated the incremental markup (MU_{RET_INCR}) for pool retailers using the following equation:

$$MU_{RET\_INCR} = \frac{CGS_{RET} + VC_{RET}}{CGS_{RET}}$$

Eq. 6.9

Where:

MU_{RET_INCR} = incremental pool retailer markup,
CGS_{RET} = pool retailer's cost of goods sold, and
VC_{RET} = pool retailer's variant costs.

The markup results for pool retailers can be found from Table 6.5.10 to Table 6.5.14.

6.4.4 Pool Builder Markup

The type of financial data used to estimate pool contractor markups is also available for pool builders from the 2017 Economic Census. To estimate pool builder markups for EPHs and GPHs, DOE collected financial data from the *All Other Specialty Trade Contractors* (NAICS 238990)[10] sector from 2017 U.S. Economic Census, which is the most disaggregated and most up to date series that includes outdoor swimming pool construction. The markup results for pool retailers can be found in Table 6.5.15.

6.5 DERIVATION OF MARKUPS

6.5.1 Manufacturer Markup

DOE used U.S. Security and Exchange Commission (SEC) 10-K reports from publicly owned EPH and GPH manufacturing companies to estimate manufacturer markups. Table 6.5.1 presents manufacturer markups for the product classes considered in this analysis.

Table 6.5.1 Manufacturer Markups of Electric and Gas-fired Pool Heaters

Product Class	Markup
Electric Pool Heaters	1.39
Gas-fired Pool Heaters	1.44

6.5.2 Wholesaler Markups

6.5.2.1 Pool Wholesaler Markups in Residential and Commercial Applications

The annual SEC form 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. The average baseline and incremental markups from 10-K report for PoolCorp in the past five years were summarized in Table 6.5.2. DOE assumed that the average markups for PoolCorp are representative of the wholesaler markups of EPHs as PoolCorp accounts for a significant fraction of the wholesale market.

Table 6.5.2 Pool Wholesaler Expenses and Markups

Company	**Financial Figures $1,000**	**Year**				
		2017	**2018**	**2019**	**2020**	**2021**
PoolCorp	**Net Sales**	2,788,188	2,998,097	3,199,517	3,936,623	5,295,584
	Cost of Sales	1,982,899	2,127,924	2,274,592	2,805,721	3,678,492
	Operating Profit	284,371	313,889	341,246	464,027	832,784
	Baseline MU	1.41	1.41	1.41	1.40	1.44
	Incremental MU	1.14	1.15	1.15	1.17	1.23
	Average (Baseline/Incremental)	**1.41/1.17**				

Source: U.S. Securities and Exchange Commission, 10-K reports 2017 to 2021. [4]

In one of the distribution channels under the replacement market for EPHs and GPHs, the manufacturer sells the product to a buying group, who in turn sells it to a pool contractor, who in turn sells it to the consumer. Since the buying groups have the ability to leverage their collective purchasing power to negotiate price reductions from manufacturers, DOE assumed the markups for buying groups are around half of the value of wholesaler's markups. The resulting baseline and incremental markups for buying groups are 1.20 and 1.09, respectively.

6.5.2.2 HVAC Wholesaler Markups in Commercial Applications

The 2017 AWTS data for hardware and plumbing and heating equipment and supplies merchant wholesale provide total sales data and detailed operating expenses that are most relevant to consumer water heater wholesalers. To construct a complete data set for estimating markups, DOE took the historical sales and gross margins published separated from the 2017 AWTS to construct a complete income statement for hardware and plumbing and heating equipment and supplies merchant to estimate both baseline and incremental markups. Table 6.5.3 summarizes them at the national aggregated level as cost-per-dollar sales revenue in the first data column. These wholesaler markups are applicable to both EPHs and GPHs in commercial applications.

Table 6.5.3 HVAC Wholesaler Expenses and Markups

Descriptions	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales	0.713	1.000
Labor and Occupancy Expenses	0.161	0.226
Other Operating Expenses	0.066	0.092
Operating Profit	0.061	0.085
Wholesaler Baseline Markup ($MU_{WHOLE\ BASE}$)		**1.403**
Incremental Markup ($MU_{WHOLE\ INCR}$)		**1.177**

Source: U.S. Census, 2017 Annual Wholesale Trade Survey

6.5.3 Pool Contractor, Mechanical Contractor, and General Contractor Markups

6.5.3.1 Pool Contractor Markups for Residential and Commercial Applications

The 2017 Economic Census provides Geographic Area Series for the *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 238220) sector, which contains national average sales and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the cost breakdown of gross margin, including labor expenses, occupancy expenses, other operating expenses, and profit. The gross margin provided by the U.S. Census is disaggregated enough that DOE was able to determine the invariant (labor and occupancy expenses) and variant (other operating expenses and profits) costs for this particular sector. By using the equation mentioned in section 6.4.2, baseline and incremental markups were estimated. The markup results representing the plumbing, heating and air-conditioning contractor industry at the national aggregated level are presented in Table 6.5.4. (Appendix 6A contains the full set of data.)

Table 6.5.4 Pool Contractor Expenses and Markups Based on Census Bureau Data

Description	Pool Contractor Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Product Sales: Cost of goods sold	0.713	1.00
Labor Expenses: Salaries (indirect) and benefits	0.120	0.17
Occupancy Expense: Rent, maintenance, and utilities	0.015	0.02
Other Operating Expenses: Depreciation, advertising, and insurance.	0.074	0.10
Net Profit Before Taxes	0.079	0.11
Pool Contractor Baseline Markup (MU_{CONT_BASE})		**1.40**
Pool Contractor Incremental Markup (MU_{CONT_INCR})		**1.21**

Source: U.S. Census Bureau. 2017 Economic Census: Construction: Industry Series: Detailed Statistics: 2017. Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220.[6]

6.5.3.2 Mechanical Contractors Markups in Replacement and New Construction Markets for Commercial Applications

DOE derived the baseline and incremental markups for both replacement and new construction markets using the 2012 Economic Census industrial cost data supplemented with the most recent ACCA 2005 financial data. The 2017 Economic Census provides sufficient detailed cost breakdown for the *Plumbing and HVAC Contractors* (NAICS 238220) sector so that DOE was able to estimate baseline and incremental markups for mechanical contractors. However, the 2017 Economic Census does not separate the mechanical contractor market into replacement and new construction markets. To calculate markups for these two markets, DOE utilized 2005 ACCA financial data, which reports gross margin data for the entire mechanical contractor market and for both the replacement and new construction markets.

The HVAC contractors, defined here as mechanical contractors, reported median cost data in an ACCA 2005 financial analysis of the HVAC industry. These data are shown in Table 6.5.5.

Table 6.5.5 Baseline Markup, All Mechanical Contractors

Description	**Contractor Expenses or Revenue**	
	Per Dollar Sales Revenue $	**Per Dollar Cost of Goods $**
Direct Cost of Equipment Sales: Cost of goods sold	0.7286	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2714	0.372
Baseline Markup ($MU_{MECH\ CONT\ BASE}$)		**1.372**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.[8]

Table 6.5.6 summarizes the gross margin and resulting baseline markup data for all mechanical contractors that serve the replacement and new construction markets.

Table 6.5.6 Baseline Markups for the Replacement and New Construction Markets, All Mechanical Contractors

Description	Contractor Expenses or Revenue by Market Type			
	Replacement		New Construction	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.7031	1.000	0.745	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2969	0.422	0.255	0.342
Baseline Markup (*MUMECH CONT BASE*): Revenue per dollar cost of goods	NA	**1.422**	NA	**1.342**
% Difference from Aggregate Mechanical Contractor Baseline MU	NA	**3.63%**	NA	**-2.20%**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.[8]

Using the average baseline markups estimated for replacement and new construction market from Table 6.5.6 and the average baseline markup for all mechanical contractors from Table 6.5.5, DOE calculated that the baseline markups for the replacement and new construction markets are 3.63 percent higher and 2.20 percent lower, respectively, than for all mechanical contractors serving all markets.

The markup deviations (*i.e.,* 3.63 percent higher and 2.20 percent lower for the replacement and new construction markets, respectively) derived for all mechanical contractors were then applied to the baseline markup of 1.40 and the incremental markup of 1.21 estimated for the *Plumbing and HVAC Contractors* (NAICS 238220) sector in Table 6.5.4. DOE assumed that this deviation applies equally to the baseline and incremental markups calculated from the 2012 Economic Census. The results of the baseline and incremental markups for the replacement and new construction markets served by mechanical contractors are shown in Table 6.5.7.

Table 6.5.7 Markups for the Replacement and New Construction Markets in Commercial Applications, All Mechanical Contractors

	Baseline Markup	Incremental Markup
Replacement Market	1.47	1.27
New Construction Market	1.39	1.20

6.5.3.3 General Contractor Markups in New Construction Market for Commercial Applications

DOE derived markups for general contractors from the commercial building construction sectors in U.S. 2017 Economic Census data[7] to reflect the commercial applications of EPHs and

GPHs. Similar to the data for mechanical contractors, Table 6.5.8 summarizes the expenses for general contractors in commercial building construction at the national aggregated level as expenses per dollar sales revenue in the first data column. (Appendix 6A contains the full set of data.)

Table 6.5.8 Commercial Building General Contractor Expenses and Markups

Description	Wholesale Firm Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.794	1.00
Labor Expenses: Salaries (indirect) and benefits	0.063	0.08
Occupancy Expense: Rent, maintenance, and utilities	0.005	0.01
Other Operating Expenses: Depreciation, advertising, and insurance.	0.033	0.04
Net Profit Before Taxes	0.105	0.13
Baseline Markup (*MUGEN CONT BASE*)		**1.26**
Incremental Markup (*MUGEN CONT INCR*)		**1.17**

Source: U.S. Census Bureau. 2017. Sector 236220 (Commercial Building Construction). Construction: Industry Series: Detailed Statistics for Establishments: 2017.[7]

6.5.4 Pool Retailer Markups

As mentioned previously, DOE developed two retailer markups for EPHs and GPHs, one for the wholesaler to retailer distribution channel and the other is for the direct pool retail sales channel. The associated market shares are provided in the 2022 Pkdata report,[1] as shown in Table 6.5.9. Based on this data, DOE estimated that the wholesaler to retailer distribution channel (Mass Merchant, Club, and Home Center) represents 16 percent of pool heater shipments, while direct pool retail sales channel (Pool Products Specialty Retailer and Online) represents the remaining 84 percent of pool heater shipments.

Table 6.5.9 Market Share of Pool Accessories Retail Sales by Retailer Type

Retailer Type	Distribution Channel Type	Market Share (%)
Pool Products Specialty Retailer	Direct Pool Retail	70
Mass Merchant	Wholesaler to Retailer	7
Club	Wholesaler to Retailer	6
Home Center	Wholesaler to Retailer	3
Online	Direct Pool Retail	14

6.5.4.1 Pool Retailer (Wholesaler to Retail Distribution Channel) Markups

DOE estimated the first type of pool retailers markups (wholesaler to retail distribution channel) by using annual 10-K reports for major mass merchants, membership clubs, and home improvement centers[11] along with their associated market shares provided in the 2022 Pkdata report. Table 6.5.10 summarizes the baseline and incremental markups for each retailer considered. Table 6.5.11 summarizes the markups and associated weights to derive the overall weighted-average baseline and incremental markups for the wholesaler to retail distribution channel as 1.31 and 1.07, respectively.

Table 6.5.10 Mass Merchant, Club, and Home Improvement Center Expenses and Markups

Company	Financial Figures $1,000,000	Year				
		2017	**2018**	**2019**	**2020**	**2021**
Wal-Mart	**Net Sales**	500,343	514,405	519,926	555,233	567,762
	Cost of Sales	373,396	385,301	394,605	420,315	429,000
	Operating Profit	20,437	21,957	20,568	22,548	25,942
	Baseline MU	1.34	1.34	1.32	1.32	1.32
	Incremental MU	1.05	1.06	1.05	1.05	1.00
	Average (Baseline/Incremental)	**1.33/1.04**				
Costco	**Net Sales**	129,025	141,576	152,703	166,761	195,929
	Cost of Sales	11,882	123,152	132,886	144,939	170,684
	Operating Profit	4,111	4,480	4,737	5,435	6,708
	Baseline MU	1.15	1.15	1.15	1.15	1.15
	Incremental MU	1.04	1.04	1.04	1.04	1.04
	Average (Baseline/Incremental)	**1.15/1.04**				
The Home Depot	**Net Sales**	100,904	108,203	110,225	132,110	151,157
	Cost of Sales	66,548	71,043	72,653	87,257	100,325
	Operating Profit	14,681	15,530	15,843	18,278	23,040
	Baseline MU	1.52	1.52	1.52	1.51	1.51
	Incremental MU	1.22	1.22	1.22	1.21	1.23
	Average (Baseline/Incremental)	**1.52/1.22**				
Lowe's	**Net Sales**	68,619	71,309	72,148	89,597	96,250
	Cost of Sales	46,185	48,401	49,205	60,025	64,194
	Operating Profit	6,586	4,018	6,314	9,647	12,093
	Baseline MU	1.49	1.47	1.47	1.49	1.50
	Incremental MU	1.14	1.08	1.13	1.16	1.19
	Average (Baseline/Incremental)	**1.48/1.14**				

Source: U.S. Securities and Exchange Commission, 10-K reports 2017 to 2021.[11]

Table 6.5.11 Summary of Markups and Market Share for Pool Retailer (Wholesaler to Retail Distribution Channel)

Retailer Type	Representative Company	Baseline MU	Incremental MU	Market Share (%)
Mass Merchant	Wal-Mart	1.33	1.04	35
Club	Costco	1.15	1.04	30
Home Center*	The Home Depot, Lowe's	1.50	1.18	15
Online		2.05	1.50	20
Weighted Average		**1.45**	**1.15**	**100**

* Average of The Home Depot and Lowe's markup values.

6.5.4.2 Pool Retailer (Direct Retail Sales) Markups

For the direct retail sales, one of the major large pool specialty stores in the U.S. is Leslie's Swimming Pool Supplies. DOE obtained their 10-K reports from 2018 to 2021[12] and assumed that the baseline and incremental markups derived from their 10-K reports are representative of the pool products specialty stores in general. Table 6.5.12 shows the expenses and derived markups for Leslie's Swimming Pool Supplies.

Table 6.5.12 Leslie's Inc. Expenses and Markups

Company	Financial Figures $1,000	Year			
		2018	**2019**	**2020**	**2021**
Leslie's Inc.	**Net Sales**	1,112,229	928,203	1,112,229	1,342,917
	Cost of Sales	651,516	548,463	651,516	747,757
	Operating Profit	146,375	121,588	146,375	209,085
	Baseline MU	1.71	1.69	1.71	1.80
	Incremental MU	1.22	1.22	1.22	1.28
	Average (Baseline/Incremental)	**1.73/1.24**			

Source: U.S. Securities and Exchange Commission, 10-K reports from 2018 to 2021

DOE estimated the overall markups for pool retailer based on industry-level financial data for the *Miscellaneous Store Retailers* (NAICS 453) sector from the U.S. Census Bureau's 2017 ARTS,[9] which is the most recent survey available with detailed operating expenses for this particular sector.

Table 6.5.13 shows the calculation of the baseline and incremental retailer markups. (Appendix 6A contains the full set of data.)

Table 6.5.13 Markup Estimation for Miscellaneous Store Retailers

Descriptions	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Product Sales: Cost of goods sold	0.484	1.00
Labor Expenses: Salaries and benefits	0.187	0.39
Occupancy Expense: Rent, maintenance, and utilities	0.089	0.18
Other Operating Expenses: Depreciation, advertising, and insurance.	0.110	0.23
Operating Profit	0.131	0.27
Pool Retailer Baseline Markup (MU_{RET_BASE})		2.07
Pool Retailer Incremental Markup (MU_{RET_INCR})		1.50

Source: U.S. Census Bureau's 2017 Annual Retail Trade Survey (NAICS 453 Miscellaneous Store Retailers).[9]

Table 6.5.14 summarizes the markups and associated weights to derive the overall weighted-average baseline and incremental markups for the direct retail sales channel as 1.77 and 1.27, respectively.

Table 6.5.14 Summary of Markups and Market Share for Pool Retailer (Direct Retail Distribution Channel)

Retailer Type	Representative Company	Baseline MU	Incremental MU	Market Share (%)
Pool Products Specialty Stores	Leslie's Inc.	1.73	1.24	87.5
Online		2.05	1.50	12.5
Weighted Average		**1.77**	**1.27**	**100**

6.5.5 Pool Builder Markups

DOE derived the baseline and incremental markups for pool builders using the 2017 Economic Census industrial cost data for the *All Other Specialty Trade Contractors* (NAICS 238990) sector,[10] which includes businesses associated with outdoor swimming pool construction. Even though this aggregated industrial series also consists of many other contracting businesses, this series is the most disaggregated sector that includes work related to building swimming pool. By using the equation mentioned above, baseline and incremental markups were estimated, the results are summarized in Table 6.5.15. (Appendix 6A contains the full set of data.)

Table 6.5.15 Pool Builder Expenses and Markups

Description	General Contractor Expenses or Revenue	
	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Product Sales: Cost of goods sold	0.692	1.00
Labor Expenses: Salaries (indirect) and benefits	0.104	0.15
Occupancy Expense: Rent, maintenance, and utilities	0.023	0.03
Other Operating Expenses: Depreciation, advertising, and insurance.	0.098	0.14
Net Profit Before Taxes	0.083	0.12
Pool Builder Baseline Markup		**1.44**
Pool Builder Incremental Markup		**1.26**

Source: U.S. Census Bureau. 2017. All Other Specialty Trade Contractors. Sector 23: 238990. Construction: Industry Series Detailed Statistics: 2017[10]

6.6 DERIVATION OF CENSUS REGIONS MARKUPS

The ownership of EPHs and GPHs has very distinct regional pattern in which places with warmer climate have higher penetration rate (*e.g.*, Florida or California). To reflect this regional difference, regional markups were calculated for pool contractors and pool builders in residential applications and for wholesalers, mechanical and general contractors in commercial applications because their markups are expected to be impacted the most depending where the owners reside. Hence, to make the analysis more accurate, state-level markups were calculated for each consumer pool heater product class in residential and commercial applications.

6.6.1 Estimation of Regional HVAC Wholesaler Markups for Commercial Applications

The 2017 AWTS does not provide state-level data; hence DOE developed the regional wholesaler markups based on the regional income statement from the 2013 HARDI Profit Report.[15] DOE estimated baseline and incremental markups for each of the seven HARDI regions (Northeastern, Mid-Atlantic, Southwestern, Great Lakes, Central, Southwestern, and Western) as well as at the national level using the methodology shown in Table 6.5.3. Next, the national to regional markup ratio was calculated, and each state in each region was assigned the corresponding ratio for the region to which it belongs. Then, DOE applied that ratio to the national average wholesaler baseline and incremental markups to derive the state-level wholesaler baseline and incremental markups. The results are summarized in Table 6.6.1.

Table 6.6.1 Wholesaler Markups in Commercial Applications by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.370	1.173	Montana	1.447	1.186
Alaska	1.447	1.186	Nebraska	1.405	1.191
Arizona	1.447	1.186	Nevada	1.447	1.186
Arkansas	1.388	1.189	New Hampshire	1.407	1.146
California	1.447	1.186	New Jersey	1.396	1.167
Colorado	1.405	1.191	New Mexico	1.388	1.189
Connecticut	1.407	1.146	New York	1.407	1.146
Delaware	1.396	1.167	North Carolina	1.370	1.173
District of Colum.	1.396	1.167	North Dakota	1.405	1.191
Florida	1.370	1.173	Ohio	1.394	1.173
Georgia	1.370	1.173	Oklahoma	1.388	1.189
Hawaii	1.447	1.186	Oregon	1.447	1.186
Idaho	1.447	1.186	Pennsylvania	1.395	1.170
Illinois	1.405	1.191	Rhode Island	1.407	1.146
Indiana	1.394	1.173	South Carolina	1.370	1.173
Iowa	1.405	1.191	South Dakota	1.405	1.191
Kansas	1.405	1.191	Tennessee	1.370	1.173
Kentucky	1.394	1.173	Texas	1.388	1.189
Louisiana	1.388	1.189	Utah	1.447	1.186
Maine	1.407	1.146	Vermont	1.407	1.146
Maryland	1.396	1.167	Virginia	1.396	1.167
Massachusetts	1.407	1.146	Washington	1.447	1.186
Michigan	1.394	1.173	West Virginia	1.394	1.173
Minnesota	1.405	1.191	Wisconsin	1.405	1.191
Mississippi	1.370	1.173	Wyoming	1.405	1.191
Missouri	1.405	1.191			

6.6.2 Estimation of Regional Pool Contractor and Mechanical Contractor Markups

The 2017 Economic Census provides Geographic Area Series for the *Plumbing, Heating and Air-Conditioning Contractors* (NAICS 238220) sector, which contains state-level sale and detailed cost data allowing DOE to estimate both baseline and incremental markups for pool contractors in residential applications, as shown in Table 6.6.2. (Appendix 6A contains the full set of data.)

Table 6.6.2 Pool Contractor Markups by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.439	1.249	Montana	1.425	1.265
Alaska	1.535	1.333	Nebraska	1.412	1.242
Arizona	1.328	1.156	Nevada	1.372	1.188
Arkansas	1.327	1.167	New Hampshire	1.362	1.173
California	1.477	1.277	New Jersey	1.483	1.288
Colorado	1.382	1.191	New Mexico	1.355	1.179
Connecticut	1.430	1.222	New York	1.444	1.264
Delaware	1.440	1.236	North Carolina	1.418	1.225
District of Colum.	1.390	1.244	North Dakota	1.314	1.150
Florida	1.421	1.218	Ohio	1.410	1.214
Georgia	1.498	1.314	Oklahoma	1.400	1.190
Hawaii	1.464	1.278	Oregon	1.485	1.280
Idaho	1.369	1.211	Pennsylvania	1.454	1.242
Illinois	1.405	1.223	Rhode Island	1.349	1.169
Indiana	1.368	1.200	South Carolina	1.460	1.262
Iowa	1.321	1.153	South Dakota	1.343	1.171
Kansas	1.359	1.193	Tennessee	1.415	1.189
Kentucky	1.425	1.245	Texas	1.423	1.232
Louisiana	1.458	1.257	Utah	1.337	1.183
Maine	1.319	1.168	Vermont	1.371	1.191
Maryland	1.390	1.214	Virginia	1.449	1.258
Massachusetts	1.381	1.208	Washington	1.323	1.127
Michigan	1.477	1.274	West Virginia	1.431	1.215
Minnesota	1.346	1.186	Wisconsin	1.385	1.213
Mississippi	1.300	1.143	Wyoming	1.348	1.166
Missouri	1.279	1.114			

In commercial applications, the baseline and incremental markups were estimated for both replacement and new construction markets for each state, DOE applied the markup deviations (*i.e.,* 3.6 percent higher and 2.2 percent lower for the replacement and new construction markets, respectively) derived in section 6.5.3.2 to the statewide baseline and incremental markups. DOE assumed that this deviation of replacement and new construction markets applies equally to the baseline and incremental markups, as shown in Table 6.6.4.

Table 6.6.3 Mechanical Contractor Markups for Commercial Applications by State

State	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Alabama	1.491	1.294	1.408	1.221
Alaska	1.590	1.381	1.501	1.303
Arizona	1.376	1.198	1.298	1.130
Arkansas	1.376	1.209	1.298	1.141
California	1.530	1.323	1.444	1.249
Colorado	1.432	1.234	1.351	1.164
Connecticut	1.482	1.266	1.399	1.195
Delaware	1.492	1.281	1.409	1.209
District of Colum.	1.441	1.289	1.360	1.217
Florida	1.472	1.262	1.390	1.191
Georgia	1.552	1.361	1.465	1.285
Hawaii	1.517	1.324	1.431	1.250
Idaho	1.419	1.255	1.339	1.185
Illinois	1.456	1.267	1.374	1.196
Indiana	1.418	1.244	1.338	1.174
Iowa	1.369	1.195	1.292	1.128
Kansas	1.408	1.237	1.329	1.167
Kentucky	1.477	1.290	1.394	1.218
Louisiana	1.511	1.302	1.426	1.229
Maine	1.367	1.210	1.290	1.142
Maryland	1.441	1.258	1.360	1.188
Massachusetts	1.431	1.251	1.351	1.181
Michigan	1.530	1.320	1.444	1.246
Minnesota	1.396	1.230	1.318	1.161
Mississippi	1.348	1.185	1.273	1.118
Missouri	1.326	1.155	1.251	1.090
Montana	1.477	1.311	1.394	1.237
Nebraska	1.463	1.287	1.381	1.214
Nevada	1.421	1.231	1.341	1.162
New Hampshire	1.411	1.216	1.332	1.147
New Jersey	1.537	1.335	1.451	1.260
New Mexico	1.404	1.221	1.325	1.153
New York	1.496	1.310	1.412	1.236
North Carolina	1.469	1.270	1.387	1.198
North Dakota	1.363	1.193	1.286	1.126
Ohio	1.461	1.258	1.379	1.187
Oklahoma	1.451	1.233	1.369	1.164
Oregon	1.539	1.326	1.453	1.252
Pennsylvania	1.507	1.287	1.422	1.214
Rhode Island	1.399	1.212	1.320	1.144
South Carolina	1.513	1.307	1.427	1.234
South Dakota	1.393	1.214	1.315	1.146
Tennessee	1.467	1.232	1.384	1.162
Texas	1.475	1.277	1.392	1.205
Utah	1.386	1.226	1.308	1.157
Vermont	1.421	1.234	1.341	1.165
Virginia	1.501	1.303	1.417	1.230
Washington	1.371	1.168	1.294	1.102
West Virginia	1.484	1.263	1.401	1.192
Wisconsin	1.435	1.257	1.354	1.186
Wyoming	1.397	1.208	1.319	1.140

6.6.3 Estimation of Regional Pool Builder Markups

To derive regional pool builder markups for EPHs and GPHs in the new swimming pool construction market, DOE used the Geographic Area Series for *All Other Specialty Trade Contractors* (NAICS 238990) from the 2017 Economic Census. This series consist of statewide sales and cost data required to calculate baseline markups for each state. However, a few cost categories were not disclosed for some states due to confidentiality agreement; therefore, the estimation of their incremental markups became unattainable. For states with insufficient cost data, DOE used the average incremental markup of their neighboring states as the proxy. The final results are summarized in Table 6.6.5. (Appendix 6A contains the full set of data.)

Table 6.6.4 Pool Builder Markups by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.434	1.271	Montana	1.406	1.246
Alaska	1.374	1.233	Nebraska	1.503	1.321
Arizona	1.360	1.170	Nevada	1.508	1.344
Arkansas	1.550	1.378	New Hampshire	1.359	1.199
California	1.444	1.242	New Jersey	1.525	1.343
Colorado	1.636	1.435	New Mexico	1.550	1.364
Connecticut	1.375	1.198	New York	1.446	1.260
Delaware	1.460	1.272	North Carolina	1.476	1.312
District of Colum.	1.371	1.165	North Dakota	1.643	1.421
Florida	1.487	1.316	Ohio	1.426	1.257
Georgia	1.421	1.250	Oklahoma	1.519	1.328
Hawaii	1.527	1.283	Oregon	1.506	1.294
Idaho	1.396	1.243	Pennsylvania	1.523	1.339
Illinois	1.402	1.202	Rhode Island	1.416	1.248
Indiana	1.495	1.291	South Carolina	1.518	1.344
Iowa	1.442	1.273	South Dakota	1.366	1.190
Kansas	1.422	1.243	Tennessee	1.492	1.296
Kentucky	1.460	1.280	Texas	1.541	1.357
Louisiana	2.016	1.826	Utah	1.530	1.349
Maine	1.573	1.405	Vermont	1.339	1.187
Maryland	1.451	1.261	Virginia	1.501	1.321
Massachusetts	1.402	1.219	Washington	1.526	1.307
Michigan	1.384	1.222	West Virginia	1.483	1.265
Minnesota	1.470	1.293	Wisconsin	1.345	1.187
Mississippi	1.444	1.251	Wyoming	1.481	1.297
Missouri	1.319	1.172			

6.6.4 Estimation of Regional General Contractor Markups for Commercial Applications

In order to derive regional general contractor markups for the commercial building construction sector, DOE used the Commercial Building Construction series (NAICS 236220) from the 2017 Economic Census to derive regional general contractor markups in commercial applications of EPHs and GPHs.

For the commercial building construction sector, the type of cost data required to develop baseline and incremental markups are available; therefore, DOE used similar approach as described in section 6.4.2 to estimate state-level baseline and incremental markup for commercial general contractors. The final results are summarized in Table 6.6.7 for commercial applications (Appendix 6A contains the full set of data.)

Table 6.6.5 Builder Markups for Pool Heaters in Commercial Applications by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.308	1.230	Montana	1.385	1.294
Alaska	1.257	1.120	Nebraska	1.172	1.097
Arizona	1.257	1.179	Nevada	1.359	1.267
Arkansas	1.258	1.184	New Hampshire	1.303	1.193
California	1.257	1.162	New Jersey	1.243	1.152
Colorado	1.257	1.194	New Mexico	1.110	1.030
Connecticut	1.243	1.153	New York	1.229	1.131
Delaware	1.258	1.151	North Carolina	1.258	1.188
District of Colum.	1.258	1.152	North Dakota	1.266	1.170
Florida	1.231	1.144	Ohio	1.249	1.164
Georgia	1.258	1.187	Oklahoma	1.173	1.097
Hawaii	1.257	1.157	Oregon	1.131	1.057
Idaho	1.257	1.158	Pennsylvania	1.257	1.162
Illinois	1.261	1.185	Rhode Island	1.243	1.172
Indiana	1.337	1.228	South Carolina	1.259	1.183
Iowa	1.266	1.192	South Dakota	1.266	1.192
Kansas	1.266	1.200	Tennessee	1.185	1.107
Kentucky	1.215	1.142	Texas	1.208	1.129
Louisiana	1.258	1.170	Utah	1.741	1.657
Maine	1.243	1.153	Vermont	1.243	1.128
Maryland	1.680	1.577	Virginia	1.305	1.238
Massachusetts	1.243	1.161	Washington	1.182	1.100
Michigan	1.266	1.181	West Virginia	1.258	1.150
Minnesota	1.266	1.171	Wisconsin	1.278	1.191
Mississippi	1.258	1.150	Wyoming	1.257	1.152
Missouri	1.266	1.162			

6.7 SALES TAX

The sales tax represents state and local sales taxes that are applied to the consumer price of the product. The sales tax is a multiplicative factor that increases the consumer product price. DOE only applied the sales tax to the consumer price of the product in the replacement and new owner market, not the new construction market. The common practice for selling larger residential appliances like EPHs and GPHs in the new swimming pool construction market is that pool builders or general contractors would bear the added sales tax for the product, in addition to the cost of the product, and then mark up the entire cost in the final listing price to consumers. Therefore, no additional sales tax is necessary to calculate the consumer product price for the new swimming pool construction market.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse,[16] as shown in Table 6.7.1. These data represent weighted averages that include county and city rates.

Table 6.7.1 Average State Sales Tax Rates

State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %
Alabama	8.70	Kentucky	6.00	North Dakota	6.25
Alaska	1.30	Louisiana	9.40	Ohio	7.20
Arizona	7.30	Maine	5.50	Oklahoma	8.60
Arkansas	9.15	Maryland	6.00	Oregon	--
California	8.80	Massachusetts	6.25	Pennsylvania	6.35
Colorado	6.40	Michigan	6.00	Rhode Island	7.00
Connecticut	6.35	Minnesota	7.45	South Carolina	7.45
Delaware	--	Mississippi	7.05	South Dakota	6.00
Dist. of Columbia	6.00	Missouri	7.05	Tennessee	9.50
Florida	7.00	Montana	--	Texas	8.00
Georgia	7.40	Nebraska	6.10	Utah	7.15
Hawaii	4.45	Nevada	8.25	Vermont	6.10
Idaho	6.05	New Hampshire	--	Virginia	5.00
Illinois	8.60	New Jersey	6.60	Washington	9.30
Indiana	7.00	New Mexico	7.05	West Virginia	6.15
Iowa	6.95	New York	8.45	Wisconsin	5.45
Kansas	8.40	North Carolina	7.00	Wyoming	5.45

6.8 OVERALL MARKUPS

DOE used the overall baseline markup to estimate the consumer product price of baseline models, given the manufacturer cost of the baseline models. As stated previously, DOE considered baseline models to be products sold under existing market conditions (*i.e.,* without new energy conservation standards). The following equation shows how DOE uses the overall baseline markup to determine the product price for baseline models.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{BASE} \times Tax_{SALES}\right) = COST_{MFG} \times MU_{OVERALL\_BASE}$$

Eq. 6.10

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{BASE} = baseline replacement or new pool channel markup,
Tax_{SALES} = sales tax (replacement and new owner applications only), and

$MU_{OVERALL\_BASE}$ = baseline overall markup.

Similarly, DOE used the overall incremental markup to estimate changes in the consumer product price, given changes in the manufacturer cost from the baseline model cost resulting from an energy conservation standard to raise product energy efficiency. The total consumer product price for more energy-efficient models is composed of two components: the consumer product price of the baseline model and the change in consumer product price associated with the increase in manufacturer cost to meet the new energy conservation standard. The following equation shows how DOE used the overall incremental markup to determine the consumer product price for more energy-efficient models (*i.e.,* models meeting new energy conservation standards).

$$\begin{aligned} CPP_{STD} &= COST_{MFG} \times MU_{OVERALL\_BASE} + \Delta COST_{MFG} \times \left(MU_{MFG} \times MU_{INCR} \times Tax_{SALES} \right) \\ &= CPP_{BASE} + \Delta COST_{MFG} \times MU_{OVERALL\_INCR} \end{aligned}$$

Eq. 6.11

Where:

CPP_{STD} = consumer product price for models meeting new energy conservation standards,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
$\Delta COST_{MFG}$ = change in manufacturer cost for more energy-efficient models,
MU_{MFG} = manufacturer markup,
MU_{INCR} = incremental replacement or new pool channel markup,
Tax_{SALES} = sales tax (replacement and new owner applications only),
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline replacement or new swimming pool construction channel markup, and sales tax), and
$MU_{OVERALL\_INCR}$ = incremental overall markup.

Table 6.8.1 and Table 6.8.2 summarize the national markups for each market participant under different distribution channels in residential and commercial applications, respectively. In addition, DOE also estimated the shipment-weighted overall baseline and incremental markups for EPHs and GPHs (see Table 6.8.3). These values represent the weighted-average markups based on the state-level markup values and shipment data by state as weight.

Table 6.8.1 Summary of Overall Markups for Electric Pool Heaters and Gas-fired Pool Heaters in Residential Applications

Replacement and New Owner Market	Manufacturer → Wholesaler → Pool Contractor → Consumer		Manufacturer → Pool Contractor → Consumer	
Market Share	45%		25%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Wholesaler/Distributor	1.41	1.17		
Pool Heater Contractor	1.43	1.23	1.43	1.23
Pool Retailer			1.31	1.07
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup (EPHs)	**3.01**	**2.15**	**2.79**	**1.96**
Overall Markup (GPHs)	**3.12**	**2.22**	**2.89**	**2.03**
Replacement and New Owner Market	Manufacturer → Buying Group → Pool Contractor → Consumer		Manufacturer → Pool Retailer → Consumer	
Market Share	5%		25%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Buying Group	1.21	1.08		
Pool Heater Contractor	1.43	1.23		
Pool Retailer			1.65	1.21
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup (EPHs)	**2.58**	**1.98**	**2.46**	**1.80**
Overall Markup (GPHs)	**2.67**	**2.05**	**2.55**	**1.87**
Replacement and New Owner Market	Manufacturer → Online Retailer → Consumer			
Market Share	15%			
	Baseline	Incremental		
Manufacturer	1.39 or 1.44			
Online Retailer	1.69	1.42		
Sales Tax	1.073	1.073		
Overall Markup (EPHs)	**2.52**	**2.12**		
Overall Markup (GPHs)	**2.61**	**2.19**		
New Swimming Pool Construction	Manufacturer → Wholesaler → Pool Builder → Consumer		Manufacturer → Buying Group → Pool Builder → Consumer	
Market Share	45%		45%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Wholesaler/Distributor	1.41	1.17	1.21	1.08
Pool Builder	1.47	1.28	1.47	1.28
Overall Markup (EPHs)	**2.88**	**2.08**	**2.47**	**1.92**
Overall Markup (GPHs)	**2.98**	**2.16**	**2.56**	**1.99**
New Swimming Pool Construction	Manufacturer → Pool Builder → Consumer			
Market Share	10%			
	Baseline	Incremental		
Manufacturer	1.39 or 1.44			
Online Retailer	1.69	1.42		
Overall Markup (EPHs)	2.35	1.97		
Overall Markup (GPHs)	2.43	2.04		

Note: Components may not multiply to the total markup due to rounding.

Table 6.8.2 Summary of Overall Markups for Pool Heaters in Commercial Applications

Replacement and New Owner Market	Manufacturer → Wholesaler → Pool Contractor → Consumer		Manufacturer → HVAC wholesaler → Mechanical Contractor → Consumer	
Market Share	30%		0.5%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Wholesaler/Distributor	1.41	1.17	1.40	1.18
Pool Heater Contractor	1.43	1.23	1.47	1.27
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup (EPHs)	**3.01**	**2.15**	**3.07**	**2.24**
Overall Markup (GPHs)	**3.12**	**2.22**	**3.18**	**2.32**
Replacement and New Owner Market	Manufacturer → Buying Group → Pool Contractor → Consumer		Manufacturer → National Account → Consumer	
Market Share	10%		20%	
	Baseline	Baseline	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Buying Group/National Account	1.21	1.08	1.24	1.14
Pool Heater Contractor	1.43	1.23		
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup (EPHs)	**2.58**	**1.98**	**1.85**	**1.70**
Overall Markup (GPHs)	**2.67**	**2.05**	**1.92**	**1.76**
Replacement and New Owner Market	Mfr → Pool Contractor → Consumer			
Market Share	10%			
	Baseline	Incremental		
Manufacturer	1.39 or 1.44			
Wholesaler/Distributor	1.41	1.17		
Pool Contractor	1.43	1.23		
Sales Tax	1.073	1.073		
Overall Markup (EPHs)	**3.01**	**2.15**		
Overall Markup (GPHs)	**3.12**	**2.22**		
New Swimming Pool Construction	Manufacturer → Wholesaler → Pool Builder → Consumer		Manufacturer → Buying Group → Pool Builder → Consumer	
Market Share	30%		10%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Wholesaler/Distributor	1.41	1.17	1.21	1.08
Pool Builder	1.47	1.28	1.47	1.28
Overall Markup (EPHs)	**2.88**	**2.08**	**2.47**	**1.92**
Overall Markup (GPHs)	**2.98**	**2.16**	**2.56**	**1.99**
New Swimming Pool Construction	Manufacturer → HVAC Wholesaler → Pool Builder → Contractor → Consumer		Manufacturer → National Account → Consumer	
Market Share	40%		10%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.39 or 1.44		1.39 or 1.44	
Wholesaler/Distributor	1.40	1.18	1.37	1.10
Pool Builder	1.47	1.28		
Mechanical Contractor	1.39	1.20		
Overall Markup (EPHs)	**3.98**	**2.52**	**1.90**	**1.53**
Overall Markup (GPHs)	**4.12**	**2.61**	**1.97**	**1.58**
New Swimming Pool Construction	Mfr → Pool Builder → Consumer			
Market Share	10%			
	Baseline	Incremental		
Manufacturer	1.39 or 1.44			
Pool Builder	1.47	1.28		
Overall Markup (EPHs)	**2.04**	**1.78**		
Overall Markup (GPHs)	**2.12**	**1.84**		

Note: Components may not multiply to the total markup due to rounding.

Table 6.8.3 Summary of Total Markups for Electric and Gas-fired Pool Heaters

Product Class	Baseline Markup	Incremental Markup
Electric Pool Heaters	2.67	2.01
Gas-fired Pool Heaters	2.78	2.09

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

The purpose of the energy use analysis is to determine the annual energy consumption of electric pool heaters (EPHs) and gas-fired pool heater (GPHs) in use in the United States and to assess the energy savings potential of increases in integrated thermal efficiency (TE_i). These annual energy consumption estimates are used in life-cycle cost (LCC) and payback period (PBP) analysis described in chapter 8 to determine the operating cost savings[a] consumers would realize from more energy-efficient products and in the national impact analysis (NIA) described in chapter 10 to determine the unit energy consumption and the operating cost savings to estimate the national energy savings (NES) and net present value (NPV) respectively. In contrast to the current federal pool heater test procedure,[1] which uses typical operating conditions in a laboratory setting, the energy use analysis in this chapter seeks to estimate the distribution of annual energy consumption for pool heaters in the field across a range of climate zones, swimming pool and spa characteristics, and applications.

As described in section 7.2, to represent actual residential and commercial consumers[b] likely to purchase and use pool heaters, U.S. Department of Energy (DOE) developed a pool heater sample based primarily on data from the Energy Information Administration's (EIA) 2015 Residential Energy Consumption Survey (RECS 2015)[2] and EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012).[3] These are the latest available surveys for residential households and commercial buildings.[c] DOE used the samples not only to determine pool heater annual energy consumption, but also as the basis for conducting the LCC analysis.

As described in section 7.3, DOE estimated the existing pool heater energy consumption by using equipment characteristics, swimming pool and spa characteristics, and other assumptions about the energy consumption. For example, for each sampled pool heater used in residential applications, DOE used the RECS-reported energy consumption for pool and/or spa heating and the estimated energy efficiency of the existing pool heater, to calculate the pool-heating load[d] of each sample swimming pool and/or spa. To complete the analysis, DOE calculated the energy consumption of the baseline and alternative (more energy efficient) pool heaters installed in place of the existing pool heater.

[a] Energy costs, calculated using annual energy consumption and energy prices, are the most significant component of consumer operating costs.
[b] To accurately estimate the costs and benefits of potential standards, DOE must consider all applications of the covered product, including commercial-sector usage of a consumer product. In addition, the standards definition of pool heaters does not include a capacity limit, so DOE included commercial-sized pool heaters in its analysis.
[c] EIA plans is currently processing the RECS 2020 data and it usually takes a couple of years to fully release the data. Also note that EIA is currently processing the CBECS 2018 data which is expected to be fully released in late 2021. Until that time, RECS 2015 and CBECS 2012 remains the most recent full data release.
[d] The pool heater heating load represents the amount of heating required for a pool throughout a year.

7.2 POOL HEATER SAMPLE

DOE derived seven separate pool heater samples for each pool heater market type (including pool heaters used in either residential or commercial applications)[e] as follows:

1) Pool heaters in single family homes that serve a swimming pool only,
2) Pool heaters in single family homes that serve both a swimming pool and spa,[f]
3) Pool heaters in single family homes that serve a spa only,[g]
4) Pool heaters in single-family community swimming pools or spas,
5) Pool heaters in multi-family community swimming pools or spas,
6) Pool heaters in indoor commercial swimming pools or spas, and
7) Pool heaters in outdoor commercial swimming pools or spas.

DOE used RECS 2015 to establish a sample of single-family homes that use an electric or gas-fired pool heater in a pool heater market type 1, 2, and 3 (Table 7.2.1). RECS 2015 includes energy-related data from more than 5,600 housing units that represent almost 118.2 million occupied households. RECS 2015 includes information such as the household or building owner demographics, fuel types used, months swimming pool used in the last year, energy consumption and expenditures, and other relevant data. DOE's calculation of the annual energy use for pool heaters in market types 1, 2, and 3 relied directly on energy consumption data from RECS 2015 as shown in section 7.3.3.1 to calculate the pool heater heating load. In addition, for sample subset 6 (pool heaters used in indoor swimming pools in commercial applications), CBECS 2012 records were used. CBECS 2012 includes energy-related data from more than 6,720 commercial buildings that represent almost 5.6 million buildings. CBECS 2012 includes information such as if a building has an indoor swimming pool and the energy source for the pool heater.

Both RECS 2015 and CBECS 2012 weighting indicate how commonly each household configuration occurred in the general population in 2015 or 2012, respectively. Based on manufacturer input, DOE adjusted the sample weight for electric pool heaters used in spas only (pool heater market type 3) to 1.5 percent of the original RECS weights.[h] Similarly, for gas-fired pool heaters used in spas only (pool heater market type 3), DOE adjusted the sample weight to 50 percent of the original RECS weights based on historical shipments model estimates (see

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[e] Standards established for pool heaters apply to any gas-fired and electric pool heater regardless of input capacity. DOE limited its energy use analysis to smaller commercial-sized pool heaters similar to the ones found in residential applications, because it has limited data on the number of large commercial-sized pool heaters and their energy use.
[f] RECS 2015 uses the term hot tub instead of spa. When a household has a pool heater and spa heater of the same fuel, RECS 2015 does not provide information about whether the pool heater is used for both. DOE assumes that in this case, a single pool heater is used to heat both the pool and spa.
[g] For electric pool heater sample, DOE only considered a small fraction of large spas that require a pool heater large than 11 kW. For this final rule, the fraction of spas with an electric pool heater larger than 11 kW was determined based on 2022 Pkdata.
[h] Manufacturers stated that the great majority of electric pool heaters used in spas are electric resistance pool heaters at or below 11 kW input capacity, which falls outside the scope of this rulemaking. For this analysis, DOE did not perform energy conservation standards analysis for electric spa heaters which are defined to have a rated output capacity of 11 kW or less and are factory- or field-assembled within the envelope of a spa, hot tub, or pool. Note that DOE identified the 11 kW threshold as being a typical output capacity below which electric resistance heaters are integrated in spas, hot tubs, or pools. See chapter 5 for further details.

chapter 9 for more details). Finally, DOE used 2022 Pkdata by state, RECS 2020 by state, and CBECS 2018 data by census division to weight the sample to the most recent data available.

Table 7.2.1 Selection of RECS 2015 and CBECS 2012 Records for Pool Heaters Market Type 1, 2, 3, and 6 Subsamples

Pool Heater Market Type	Algorithm	Pool Heater Type	No. of Records	DOE Sample Weight *(million)**
1) Pool heaters in single family homes that serve a swimming pool only	• Swimming pool has pool heater = Yes • Pool heater fuel type = Gas[i] or Electricity • If the house has a spa, is the spa heater of the same fuel type as the pool heater = No	GPH	24	0.083
		GPH	33	0.161
2) Pool heaters in single family homes that serve both a swimming pool and spa	• Swimming pool has pool heater = Yes • House has a spa = Yes • Pool heater fuel type = Gas or Electricity • The spa heater is of the same fuel type as the pool heater = Yes	EPH	10	0.024
		GPH	38	0.105
3) Pool heaters in single family homes that serve a spa only	• House has a spa = Yes • Spa heater fuel type = Gas or Electricity • If the house has a swimming pool with a pool heater, is the pool heater of the same fuel type as the spa heater = No	EPH	201	0.011
		GPH	59	0.082
4) Pool heaters in community pools (single-family)	• Single Family = Yes • Has pool or spa heater = No	EPH	2827	0.001
		GPH	3295	0.006
5) Pool heaters in community pools (multi-family)	• Multi-Family = Yes • Has pool or spa heater = No	EPH	927	0.003
		GPH	1030	0.021
6) Pool heaters in indoor commercial swimming pools or spas	• Building has an indoor swimming pool = Yes • Pool heater fuel type = Gas or Electricity	EPH	26	0.002
		GPH	90	0.015
7) Pool heaters in indoor commercial swimming pools or spas	• Building activity types could have an outdoor swimming pool = Yes	EPH	1751	0.010
		GPH	1483	0.002

* DOE's pool heater sample weight has been adjusted as follows: 1.5% for EPHs and 50% for GPHs of the RECS 2015 household weight. DOE's pool heater sample weight has been adjusted to match 2022 Pkdata regarding fraction of commercial indoor versus outdoor swimming pools.

Neither RECS 2015 nor CBECS 2012 have sufficient household or building information to distinguish other sample subsets (numbers 4, 5, and 7), as they do not include information about pools for common areas in multi-family residences and complexes or outdoor pools in

[i] Gas includes natural gas and propane (or LPG).

commercial buildings. To determine the market share and sample for these sample subsets DOE used a combination of sources including RECS 2015, CBECS 2012, 2009 American Housing Survey,[4] 2011 American Housing Survey,[5]and 2022 Pkdata.[6] See appendix 7A for more details.

Table 7.2.2 shows the resulting sample weights for the seven sample subsets.

Table 7.2.2 Fraction of Electric and Gas-Fired Pool Heaters by Pool Heater Market

Pool Heater Market Type ID	Description of Pool Heater Market Type	Fraction of Electric Pool Heaters (Percent)	Fraction of Gas-fired Pool Heaters (Percent)
1	Single Family with Pool Heater Serving Swimming Pool Only	65.9	40.3
2	Single Family with Pool Heater Serving Swimming Pool + Spa	19.0	26.4
3	Single Family with Pool Heater Serving Spa Only	8.8	20.4
4	Community Pools or Spas (Single-Family)	0.8	1.5
5	Community Pools or Spas (Multi-Family)	2.8	5.1
6	Commercial Indoor Pools and Spas	1.4	3.8
7	Commercial Outdoor Pools and Spas	1.3	2.5

Appendix 7A presents the RECS 2015 and CBECS 2012 variables used in this analysis and their definitions, as well as further information about the derivation of the building sample.

7.3 CALCULATION OF ENERGY CONSUMPTION

DOE modified the method stipulated in the federal pool heater test procedure[1] to calculate the annual energy consumption at the considered energy efficiency levels for each household to account for actual field conditions. To estimate the annual energy consumption of pool heaters, DOE used a number of sources including RECS 2015, CBECS 2012, a Consortium for Energy Efficiency (CEE) report,[7] a Brookhaven National Laboratory report,[8] Raypak pool heater sizer,[j] and 2022 Pkdata. Section 7.3.1 describes the determination of the annual gas consumption for GPHs and section 7.3.2 describes the determination of the annual electricity consumption for EPHs and GPHs.

7.3.1 Annual Gas Consumption for GPHs

To calculate annual gas consumption (E_F) for GPHs, DOE considered both active mode ($BOH \times Q_{IN}$), standby ($(POH - BOH) \times Q_{PR}$), and off-mode ($(8760 - POH) \times Q_{off,R} \times PH_{off}$) as shown below:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_{PR} + (8760 - POH) \times Q_{off,R} \times PH_{off}$$

Eq. 7.1

[j] https://apps.raypak.com/gas_sizing/index.php

Where:

BOH = average number of burner (active mode) operating hours per year, h/yr,
POH = average number of pool operating hours per year, h/yr,
Q_{IN} = rated fuel energy input, kBtu/h,
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, kBtu/h,
8760 = number of hours in one year, h,
$Q_{off,R}$ = average off mode fossil fuel energy consumption rate, kBtu/h, and
$PH_{off,}$ = factor to take into account fraction of pool heaters that are "winterized" and do not have any off-mode energy use, value is 0 if the pool heater is "winterized" and 1 otherwise.

The burner operating hours (*BOH*) and pool operating hours (*POH*) vary for each pool heater sampled and are described in detail in section 7.3.3 and 7.3.4, respectively. To determine pool heater input rate (Q_{IN}) for GPHs, DOE assigned a representative input rate based on the assigned swimming pool or spa size in residential or commercial applications (regardless of efficiency level)[k] based on the based on 2022 Pkdata on the fraction of swimming pools by size and DOE's sizing methodology. This results in a Q_{IN} value of 258 kBut/h and 588 kBtu/h for electric resistance pool heaters in residential and commercial applications, respectively. See Table 7.3.1 for the distribution of pool heater sizes and assigned pool heater size.

[k] In the field, many contractors install pool heater equipment based on the output capacity (not the input capacity) of the pool heater to match the pool heating needs. This means that a condensing pool heater (95 percent TE) with a 220 kBtu/h input capacity could be used to replace a baseline (82 percent TE) 250 kBtu/h input capacity, since they would have similar output capacities. In this analysis, though, DOE assumed that all GPHs are installed with the same input capacity, regardless of efficiency. Doing the analysis in this way potentially underestimates electricity use of the higher efficiency option, which is partially offset by potentially overestimating the total installed cost.

Table 7.3.1 Distribution of Swimming Pool Size and Related Pool Heater Size

Bin ID	Swimming Pool Size (gallons)	Residential Aboveground (Percent)	Residential Inground (Percent)	Commercial (Percent)	Assigned Pool Heater Size (kBtu/h)
1	2500	14.0%	5.0%	0.0%	100
2	5000	36.0%	11.0%	2.5%	150
3	10000	26.0%	18.0%	5.0%	200
4	15000	12.0%	21.0%	7.5%	250
5	20000	12.0%	18.0%	10.0%	300
6	25000		15.0%	12.5%	350
7	30000		9.0%	15.0%	400
8	40000		3.0%	17.5%	500
9	75000			12.0%	750
10	100000			7.0%	1000
11	125000			5.0%	1250
12	150000			3.0%	1500
13	175000			1.5%	1750
14	200000			1.5%	2000

DOE accounted for standby or off mode gas consumption for gas-fired pool heaters equipped with standing pilot ignition (EL 0). DOE assumed that all other efficiency levels (EL 1 to EL 3) energy use in standby mode and off mode is zero, since pool heater only fires when there is a call for heat to maintain the pool heater set-point temperature. The average energy consumption rate of continuously operating pilot light (Q_{PR}) and average off mode fossil fuel energy consumption rate ($Q_{off,\,R}$) are assigned a value of 1 kBtu/h for GPHs with a standing pilot and 0 kBtu/h otherwise (see chapter 5). Based on stakeholder comments, DOE assumed that 25 percent of all pool heater owners would weatherize their pool heater in the off mode period and thus shut off all power to the unit.[1] For example, in climates with a long and cold non-heating season, many consumers will put their pool heater in the off mode as part of the process of closing their pool for the season. Also, in parts of the country where the non-heating season is either relatively short or relatively mild or the consumer uses the pool not as often, some consumers may elect to put their pool heater in the off mode. In contrast, most pool heaters are installed in climates where there is a minimal non-heating season, so consumers in these regions are unlikely to put the pool heater in the off mode. Thus, DOE assigned a value of 0 to the PH_{off} parameter for 25 percent pool heater installations.

7.3.2 Annual Electricity Consumption for EPHs and GPHs

To calculate annual electricity consumption (E_{AE}) for EPHs and GPHs, DOE considered both active mode ($BOH \times PE$), standby ($(POH - BOH) \times P_{W,SB}$), and off-mode ($(8760 - POH) \times P_{W,off} \times PH_{off}$), and the impact of pool pump energy ($Pump_{adj}$) as shown below:

[1] For the 2015 Notice of Data Availability (NODA),[9] DOE assumed that most consumers are unlikely to set their electric pool heaters to the off mode during the non-heating season.

$$E_{AE} = BOH \times PE + (POH - BOH) \times P_{W,SB} + (8760 - POH) \times P_{W,off} \times PH_{off} + Adj_{pump\_use}$$

Eq. 7.2

Where:

BOH = average number of burner (active mode) operating hours, h/yr,
POH = average number of pool operating hours, h/yr,
PE = electrical consumption rate in the active mode, kW,
$P_{W,SB}$ = electrical energy consumption rate during standby mode, kW,
8760 = number of hours in one year, h,
$P_{W,off}$ = electrical energy consumption rate during off-mode, kW,
$PH_{off,}$ = factor to take into account fraction of pool heaters that are "winterized" and do not have any off-mode energy use, value is 0 if the pool heater is "winterized" and 1 otherwise, and
Adj_{pump_use} = adjustment to take into account differences in pump energy consumption between the different efficiency levels, kWh.

The *BOH* and *POH* vary for each pool heater sampled and are described in detail in section 7.3.3 and 7.3.4, respectively. The assigned pool heater electrical consumption rate in the active mode (*PE*) values for GPHs varies from 20 watts for EL 0 and EL 1 (non-induced draft units), 144 watts for EL 1 (induced draft units) and EL 2, and 220 watts for EL3 based on the engineering analysis (see chapter 5 for details on the derivations of these values). For EPHs, PE is equal to the input capacity (Q_{IN}), which varies by efficiency level and is calculated as follows:

$$Q_{IN} = \frac{Q_{out}}{E_t}$$

Eq. 7.3

Where:

Q_{out} = output capacity of the pool heater and
E_t = thermal efficiency, percent.

Similar to GPHs, for all electric resistance pool heaters, the output capacity (Q_{out}) is set at assigned pool heater size for the sampled swmming pool size, while the thermal efficiency (E_t) is set to 99 percent for all electric resistance pool heaters (see chapter 5). This results in a Q_{IN} value of 105 kBut/h and 239 kBtu/h for electric resistance pool heaters in residential and commercial applications, respectively. For heat pump pool heaters, Q_{out} and E_t varies by ambient conditions and more details about the derivation are provided in section 7.3.3.2. Note that for heat pump pool heaters, E_t is equal to coefficient of performance (*COP*).

DOE also accounted for the electricity use during standby mode and off mode power for all EPHs and GPHs. For EPHs, DOE assumed that the standby mode power for electric resistance pool heaters is 1.25 watts, while for heat pump pool heaters it is 5.70 watts except for the max-tech level, which is 3.13 watts (see chapter 5). For GPHs, DOE assumed that the standby mode power ($P_{W,SB}$) is 7.20 watts for non-condensing GPHs (EL 0 to EL 2) and 4.63 for condensing GPHs (EL 3) based on the engineering analysis (see chapter 5). DOE also assumed that $P_{W,SB}$ and off mode power ($P_{W,off}$) are equal for all pool heaters, except at the max-tech level for both gas-fired and electric pool heaters, which are assumed to have no off mode electricity consumption (see chapter 5). As stated in section 7.3.1, DOE assigned a value of 0 to the $PH_{off,}$ parameter for 25 percent pool heater installations to account for pool heater owners that weatherize their pool heater in the off mode period and thus shut off all power to the unit.

DOE also took into account the potential impact of the difference in operating hours for the different efficiency levels in terms of increased or decreased pool pump use (Adj_{pump_use}). The *PumpAdj* parameter is calculated as the difference between the operating hours of the baseline efficiency level (EL 0) and the higher efficiency levels multiplied times the pump power consumption. DOE assumed on average the pump power consumption to be 500 watts for all pool heaters. DOE took into account the coincidental pool heater and typical pool pump use, as well as the use of higher efficiency pumps. This decreases the impact of the additional pool pump energy use by about half compared to unadjusted estimates.[m] The typical daily pool pump operating hours are significantly higher than pool heater operating hours; therefore, the additional pool heater operating hours estimated for heat pump pool heaters would not necessarily translate directly to additional pool pump operating hours. In addition, most pool heating is achieved during the normal daily filtration pumping cycle, minimizing the need for additional pumping energy to heat pools. Finally, pool pumping is increasingly met by energy efficient dual-speed, multi-speed, and variable-speed pumps, which often run at lower flows for a longer number of hours and therefore the need for increased pumping for pool heating is further reduced.

7.3.3 Burner (Active Mode) Operating Hours

Based on the pool heater test procedure, DOE determined the annual burner operating hours (*BOH*) for each sampled home as follows:

$$BOH = \frac{PHL}{Q_{IN} \times E_t} \quad \textbf{Eq. 7.4}$$

Where:

BOH = average number of burner (active mode) operating hours, h/yr,
PHL = pool heater annual heating load, kBtu/year,
Q_{IN} = rated fuel energy input, kBtu/h, and
E_t = thermal efficiency, percent.

The derivation of the annual pool heating load (*PHL*) is discussed in the next section. As discussed in the previous section Q_{IN} for GPHs is on average 258 kBtu/h for all GPHs in residential applications and 588 kBtu/h for all GPHs in commercial applications. As discussed in

[m] Note that for the 2015 NODA, DOE did not take into account either the coincidental pool pump use or the increasing use of higher efficiency pumps.

the previous section for electric resistance pool heaters, Q_{IN} is equal to 105 kBut/h and 239 kBtu/h in residential and commercial applications, respectively. For heat pump pool heaters, Q_{out} and E_t (which is equal to *COP*), varies by ambient conditions and more details about the derivation are provided in section 7.3.3.2.

7.3.3.1 Pool Heating Load

The annual pool heating load (*PHL*) is the total heat output from the pool heater during a year of operation. For consumer pool heaters in single family homes, DOE was able to use the energy use estimates provided in RECS 2015 to estimate the pool heater load for each sampled pool or spa. For consumer pool heaters in commercial buildings, DOE calculated the *PHL* based on assumptions about size of a typical pool, ambient conditions for different locations, length of swimming pool season, and whether the pool has a cover or not.

For consumer pool heaters in single family homes (pool heater market type 1, 2, and 3), RECS 2015 provides estimates of the annual energy consumption from the household's energy bills using conditional demand analysis. The estimated annual electricity usage for EPHs used in spas and annual natural gas usage for GPHs used in swimming and hot tubs is disaggregated, but electricity use for EPHs used in swimming pools and annual propane usage for GPHs used in swimming and hot tubs is not disaggregated and instead is included in the "usage for other devices and purposes not elsewhere classified" category. Based on all the available information in RECS 2015, DOE then compared the average energy use between similar households that had an electric or gas-fired pool heater and those that did not to serve as a basis for estimating the energy use for all EPHs and GPHs in the RECS 2015 sample. The average annual energy use of existing pool heaters in 2015 derived from the RECS 2015 data, is 37.2 MMBtu/yr for GPHs and 9.9 MMBtu/yr for EPHs.

Based on the RECS 2015 data, DOE was able to determine the *PHL* using the following formula:

$$PHL = (Q_{RECS} - Q_P \times POH) \times E_{t,existing}$$

Eq. 7.5

Where:

Q_{RECS} = pool heater annual energy consumption from RECS 2015, kBtu/yr,
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, kBtu/h,
POH = average number of pool operating hours per year, h/yr, and
$E_{t,existing}$ = thermal efficiency of the household's existing pool, percent.

The derivation of operating hours (*POH*) vary for each pool heater sampled and are described in detail in section 7.3.4. The average energy consumption rate of continuously operating pilot light (Q_{PR}) and average off mode fossil fuel energy consumption rate ($Q_{off,R}$) are assigned a value of 1 kBtu/h for GPHs with a standing pilot and 0 kBtu/h otherwise (see chapter 5). DOE estimated that the thermal efficiency of the household's existing pool ($E_{t,existing}$) was 99 percent for electric resistance pool heaters, 360 percent for heat pump pool heaters, and varies from 78 percent to 95 percent for GPHs (with an estimated stock weighted average of 81.3% for GPHs installed in 2015).

To estimate the annual energy consumption of pool heaters in commercial applications (including community and multi-family pools), DOE calculated the *PHL* based on assumptions about size of a typical pool, ambient conditions for different locations, length of swimming pool season, and whether the pool has a cover or not.[n] Given that energy usage varies significantly depending on ambient conditions, usage patterns, and pool operating hours, DOE developed a distribution of *PHL* for both covered and uncovered pools based on modeling parameters from the DOE Energy Saver estimates for pool heater energy use.[10]

DOE assumed that 68 percent of pool heaters heat uncovered pools and 32 percent heat covered pools based on a pool pump study.[11] Some recent building code requirements might increase the use of pool covers in the future, but DOE noted that these building code requirements only affect pools built since these codes went into effect, and the timing of requirements for pools varies among the different States. Also, most building code requirements are focused on safety and do not necessarily require only pool covers. For example, California and Florida[12] requirements can be met using fencing or alarms instead of pool covers (note that starting from 2018 California now have to have two safety features).[13] Furthermore, there is a lack of statistics and data of the usage pattern of pool covers combined with pool heaters. For example, 2022 Pkdata shows that less than half of pool covers are installed primarily to reduce energy use, while the rest are primarily safety covers or only used to cover the pool during the winter season.

DOE's estimated average heating load for an average 30,000-gallon outdoor swimming pool in a representative city for each state without a pool cover. DOE assumes that an outdoor pool is closed if monthly average temperature is below 35 deg F. On average a 30,000-gallon indoor swimming pool is assumed to average 13 MMBtu/month. DOE assumes that the assigned swimming pool heating load can vary 50 percent more or less than the average estimated value based on various factors such as wind, shading, fraction of the time with sunlight, swimming pool setpoint water temperature, etc. If a cover is used DOE estimated that the pool heating load can decrease between 30 to 70 percent.

[n] Neither RECS 2015 or CBECS 2012 provide any energy use data for pool heaters in community pools or spas or in other commercial applications.

Table 7.3.2 Estimated Pool Heating Energy Use for 30,000 Gallon Swimming Pool

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alabama	44.0	36.5	33.1	24.7	16.5	9.5	7.5	7.5	12.6	23.6	31.3	40.4	287.3
Alaska	0.0	0.0	0.0	51.1	44.6	34.6	31.2	32.3	40.4	53.4	0.0	0.0	287.7
Arizona	40.5	34.1	34.2	27.8	22.7	14.9	8.9	9.3	14.1	23.2	32.5	39.8	301.8
Arkansas	50.1	41.6	38.4	27.3	18.4	10.9	8.7	9.0	15.0	26.8	37.0	47.4	330.5
California	35.7	30.4	32.2	28.9	26.8	22.2	18.7	18.3	18.2	23.6	28.7	35.0	318.7
Colorado	0.0	0.0	50.7	42.9	36.4	27.4	22.3	23.8	30.8	41.6	49.0	0.0	324.9
Connecticut	0.0	0.0	50.7	41.2	31.5	20.2	15.5	15.8	22.2	34.3	43.1	53.4	328.0
Delaware	0.0	0.0	48.6	37.1	27.3	16.9	13.1	13.8	20.2	32.7	43.1	52.9	305.7
District of Columbia	52.9	46.5	45.8	34.6	25.1	15.6	11.3	12.7	17.7	30.0	41.2	50.7	383.9
Florida	20.9	18.4	17.5	14.5	10.1	7.3	6.1	6.1	6.1	9.8	14.1	19.3	150.2
Georgia	47.9	41.3	38.4	28.7	21.0	12.6	10.1	11.3	15.3	27.3	36.3	46.1	336.2
Hawaii	15.8	14.3	15.5	14.1	13.1	11.9	10.9	10.6	10.2	11.3	12.6	15.5	155.7
Idaho	0.0	47.7	48.6	42.4	35.9	27.9	23.2	25.0	31.5	41.2	48.5	0.0	371.7
Illinois	0.0	0.0	52.1	41.2	31.5	20.8	15.8	17.5	23.9	37.1	48.5	0.0	288.3
Indiana	0.0	0.0	49.3	37.8	26.8	16.9	13.5	15.8	21.8	34.9	45.9	0.0	262.7
Iowa	0.0	0.0	52.9	39.2	28.7	18.4	13.5	15.5	23.9	27.4	49.0	0.0	268.4
Kansas	0.0	48.3	46.6	33.4	24.0	15.2	11.5	12.9	19.7	32.4	44.6	0.0	288.6
Kentucky	0.0	47.0	45.3	33.4	24.0	15.0	11.6	13.1	19.4	32.2	42.5	52.1	335.5
Louisiana	36.2	30.1	27.3	18.7	13.8	7.5	6.3	6.3	9.3	18.3	27.0	33.9	234.7
Maine	0.0	0.0	0.0	46.4	37.1	24.9	19.3	21.5	28.0	41.1	49.0	0.0	267.3
Maryland	0.0	47.7	47.1	37.3	26.1	16.4	13.1	13.5	19.7	32.7	42.5	52.1	348.2
Massachusetts	0.0	0.0	50.7	42.6	33.1	21.3	16.5	17.5	23.9	35.8	44.6	0.0	285.7
Michigan	0.0	0.0	52.9	41.8	31.5	21.3	17.5	17.8	24.3	38.3	48.5	0.0	293.7
Minnesota	0.0	0.0	0.0	44.3	33.3	20.8	16.5	18.4	27.5	41.2	0.0	0.0	202.0
Mississippi	45.2	38.4	32.7	23.9	16.2	9.8	7.5	7.8	11.9	24.6	32.2	41.1	291.6
Missouri	0.0	0.0	47.1	35.1	26.1	15.0	11.3	13.1	20.2	34.3	45.9	0.0	248.1
Montana	0.0	0.0	0.0	46.4	40.5	31.4	26.8	28.8	36.5	46.6	0.0	0.0	256.9
Nebraska	0.0	0.0	51.4	38.6	28.2	16.9	13.1	15.0	23.3	36.9	49.0	0.0	272.5
Nevada	46.6	38.8	38.8	31.5	26.2	18.5	14.0	14.9	20.6	30.3	38.9	45.8	365.0
New Hampshire	0.0	0.0	0.0	45.6	35.2	23.9	18.9	20.9	28.5	41.7	49.8	0.0	264.5
New Jersey	0.0	0.0	48.6	39.2	28.2	18.4	14.2	14.6	21.3	33.1	42.5	52.9	312.9
New Mexico	53.4	45.2	45.1	37.6	32.5	23.9	18.9	19.9	25.5	37.4	45.0	52.9	437.4
New York	0.0	0.0	47.9	39.1	29.1	18.4	14.2	14.6	21.3	33.1	42.6	52.1	312.4
North Carolina	50.1	43.3	41.8	31.4	22.5	13.4	10.4	12.0	17.3	28.9	38.4	48.6	358.0
North Dakota	0.0	0.0	0.0	46.4	36.4	23.3	18.4	21.5	31.1	44.6	0.0	0.0	221.6
Ohio	0.0	0.0	52.1	41.2	31.5	20.2	17.0	17.8	24.3	36.5	45.9	0.0	286.6
Oklahoma	52.9	44.6	41.8	30.7	21.5	12.6	10.2	11.5	16.9	28.7	41.2	50.1	362.6
Oregon	50.2	42.1	42.6	37.0	32.2	26.4	23.0	23.0	25.9	33.9	41.6	48.0	425.7
Pennsylvania	0.0	0.0	48.6	37.9	27.3	17.4	13.1	13.5	20.2	32.7	42.5	52.9	305.9
Rhode Island	0.0	0.0	51.4	42.6	33.1	21.8	15.8	17.8	24.3	36.5	45.2	0.0	288.7
South Carolina	42.0	35.9	33.7	24.8	17.0	10.1	7.8	8.0	11.9	22.5	31.1	40.4	285.2
South Dakota	0.0	0.0	0.0	45.0	36.4	25.3	20.3	22.2	32.1	43.0	51.7	0.0	276.1
Tennessee	43.9	36.4	33.7	24.8	17.5	10.9	7.8	9.0	13.1	24.6	33.8	41.7	297.1
Texas	38.4	32.2	27.3	19.7	13.8	8.7	7.3	7.3	9.3	87.0	27.0	35.6	313.4
Utah	0.0	0.0	49.3	41.6	35.2	26.3	20.6	21.9	29.6	40.5	48.5	0.0	313.5
Vermont	0.0	0.0	0.0	46.4	35.2	23.9	19.9	20.9	28.0	41.7	50.4	0.0	266.4
Virginia	51.4	45.2	44.0	32.9	24.0	14.5	10.4	12.0	17.3	30.0	39.9	49.3	370.9
Washington	50.2	42.1	45.2	39.8	34.9	28.4	25.7	24.6	28.0	36.8	42.3	48.0	445.9
West Virginia	0.0	47.0	46.6	35.9	26.1	16.9	13.8	14.2	20.2	32.7	43.1	52.1	348.7
Wisconsin	0.0	0.0	0.0	44.6	34.9	23.3	17.8	18.3	25.4	38.4	49.8	0.0	252.4
Wyoming	0.0	0.0	0.0	46.9	41.2	30.7	25.5	27.6	35.2	45.1	51.7	0.0	304.0
United States	44.0	36.5	33.1	24.7	16.5	9.5	7.5	7.5	12.6	23.6	31.3	40.4	287.3

The resulting average *PHL* for both EPHs and GPHs is 31.2 MMBtu/yr for residential applications (pool heater market type 1, 2, and 3) and 188.9 MMBtu/yr for commercial applications (pool heater market type 4, 5, 6, and 7). For both residential and commercial applications, the average *PHL* is 43.2 MMBtu/yr for EPHs and 52.8 MMBtu/yr for GPHs.

See Appendix 7B for more details about the derivation of *PHL*.

7.3.3.2 Field Adjusted Input Capacity, Output Capacity, and Efficiency for Heat Pump Pool Heaters

Heat pump pool heaters (HPPHs) have unique characteristics compared to electric resistance pool heaters and GPHs. DOE took into account variations of output capacity (Q_{out}), input capacity (Q_{IN}), and E_t or *COP* observed in the field based on the ambient field conditions at different geographical location. DOE used the efficiency ratings at different ambient conditions for heat pump pool heaters (based primarily on DOE's Compliance Certification Database (CCD),[14] the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance (AHRI Directory),[15] the California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDbS; CEC Database),[16] and manufacturer literature) to derive average efficiency performance curves at each efficiency level. DOE then accounted for outdoor air temperature and pool season length in determine the average field adjuted Q_{out} and *COP* value for each heat pump efficiency level for each climate region (Hot Humid, Warm, or Cold climate). Table 7.3.3 summarizes the average field-adjusted *COP* and Q_{out} values at different ambient conditions. DOE then used this data to create efficiency curves by ambient temperature for each efficiency level (see appendix 7B). These curves are then used to estimate the monthly energy use based on the ambient temperature for the installation location of the heat pump pool heater.

Table 7.3.3 COP and Q_{out} at Different Ambient Condition for HPPHs

Efficiency Level	Hot Humid*		Warm**		Cold*	
	COP (%)	Q_{out} (kBtu/h)	COP (%)	Q_{out} (kBtu/h)	COP (%)	Q_{out} (kBtu/h)
1	427%	114.6	410%	110.0	326%	87.5
2	547%	115.7	520%	110.0	381%	80.6
3	609%	115.5	580%	110.0	396%	78.9
4	628%	115.1	600%	110.0	403%	79.9
5	638%	115.0	610%	110.0	460%	83.0

* Based on available models meeting the minimum TE_i at each efficiency level.
** Assumed to be the average COP between cold and hot humid conditions. DOE assumed Warm climate is equal to DOE rated conditions for HPPH models meeting the minimum TE_i at each efficiency level.

Note that although heat pump pool heaters perform less efficiently at lower temperatures, most consumer pool heaters only operate during the swimming months, when ambient temperatures are often significantly higher than 55 °F, minimizing any loss of utility of heat pump pool heaters. DOE is not aware of any hybrid units in the market that utilize electric resistance as a heat pump pool heater backup, but this is a potential solution for a fraction of installations that might require operation at very low ambient temperatures or during a period of high demand. DOE is aware of a hybrid gas-fired/heat pump unit.[17] Also some manufacturers are developing cold climate heat pumps and heat pumps with higher input capacity to eb able to operate more efficiently in colder temperatures.

7.3.3.3 Burner Operating Hours Results

DOE estimated the operating hours 353 hours per year for EPHs and 190 hours per year for GPHs. For comparison, the pool heater test procedure average value for pool heater operating hours of 104 hours per year. Note that DOE's analysis took into account longer operating hours for heat pump pool heaters compared to gas-fired pool heaters and electric resistance pool heaters, primarily because of lower output capacity and decreased output capacity during colder months.

7.3.4 Pool Operating Hours

For single-family pool heaters (pool heater market type 1, 2, and 3), the pool operating hours (POH) is based on the months the swimming pool and/or spa is used reported in RECS 2015 for each individual household.[o] In the case, of pool heater market type 2 (which has both a swimming pool and spa), the maximum number of months between the swimming pool and spa is used in the analysis. To account for some variability in the reporting of the number of months, a triangular distribution.[p] On average, *POH* is 4,395 hours per year for GPHs and 4,290 hours per for EPHs for pool heater market type 1, 2, and 3, which is close to the pool heater test procedure average value for pool operating hours of 4,446 hours per year. Note that DOE's analysis approach took into account differences in operation between consumer pool heaters used in swimming pools compared to spas. RECS 2015 data shows that on average heated swimming pools are used 5.2 months per year (or 3,824 hours), while spas are used on average 7.4 months per year (or 5,434 hours).

For community and commercial swimming pool heaters (pool heater market type 4, 5, 6, and 7), in the absence of individual data on actual pool operating hours for each sampled swimming pool or spa, DOE used a distribution around this average to assign values for pool heater operating hours to the sample pool heaters based on installation geographical location. This approach relied on 2022 Pkdata that includes average pool operating months by State for commercial pool heater applications, as well as assigning half of pools and spas year-round use. On average, *POH* is 4,574 hours per year for GPHs and 4,589 hours per for EPHs for pool heater market type 4, 5, 6, and 7.

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[o] Note that for the 2015 NODA, DOE used RECS 2009 which did not provide the number of swimming pool and hot tub operating months for single-family pool heaters.
[p] The triangular distribution is set up for each individual sampled pool heater as: 1) minimum value is equal to 1 minus the number of months reported, 2) the maximum values is equal to 1 plus the number of months reported, and 3) the mostly likely value is the number of months reported. The overall minimum is set to be no less than the burner operating hours and have a maximum of 8760 hours.

7.4 SUMMARY OF ENERGY USE RESULTS

This section presents the average annual energy use and the average energy savings for each considered energy efficiency level compared to the baseline energy efficiency for each consumer pool heater. The results are disaggregated between pool heaters used in residential and commercial applications.[q] The LCC and PBP analysis used the results calculated for each sampled household. Table 7.4.1 and Table 7.4.2 list the average annual energy use and the average energy savings for each considered energy efficiency level compared to the baseline for electric and gas-fired pool heaters, respectively.

Table 7.4.1 Annual Energy Consumption for Electric Pool Heaters

EL	TE_i %	Annual Electricity Use	
		Total	Savings
		kWh/yr	*kWh/yr*
Residential Applications Only			
0	99	10,941	–
1	342	2,768	8,173
2	483	2,219	8,722
3	534	2,001	8,940
4	551	1,932	9,009
5	595	1,861	9,080
Commercial Applications Only			
0	99	84,899	–
1	342	23,311	61,588
2	483	19,344	65,556
3	534	17,601	67,299
4	551	16,868	68,031
5	595	16,181	68,718
All Pool Heaters			
0	99	15,497	–
1	342	4,034	11,463
2	483	3,274	12,223
3	534	2,962	12,535
4	551	2,852	12,645
5	595	2,743	12,753

[q] DOE estimated that commercial applications account for 6 percent of electric pool heater and 13 percent of gas-fired pool heater shipments in 2028. See chapter 9 for more details about the derivation of these values.

Table 7.4.2 Annual Energy Consumption for Gas-fired Pool Heaters

EL	Representative TE_i	Annual Fuel Energy Use		Annual Electricity Use	
		Total	Savings	Total	Savings
	%	*MMBtu/yr*	*MMBtu/yr*	*kWh/yr*	*kWh/yr*
Residential Applications Only					
0	69.7	44.4	–	57.4	–
1	81.3	36.9	7.5	71.8	(14.4)
2	83.3	36.0	8.4	75.8	(18.5)
3	94.7	31.8	12.6	44.5	12.8
Commercial Applications Only					
0	69.7	1192.1	–	80.7	–
1	81.3	1185.9	6.2	213.8	(133.1)
2	83.3	1157.7	34.4	288.2	(207.4)
3	94.7	1023.7	168.5	301.6	(220.8)
All Pool Heaters					
0	69.7	192.7	–	60.4	–
1	81.3	185.3	7.3	90.1	(29.7)
2	83.3	180.9	11.8	103.3	(42.9)
3	94.7	160.0	32.7	77.7	(17.4)

The actual assignment of pool heater efficiency in the no-new standards case impacts the energy use estimates of pool heaters assigned for baseline efficiency level (EL 0) compared to higher efficiency levels (EL 1-5 for EPHs and EL 1-3 for GPHs).[r] For example, gas-fired pool heaters with standing pilot are banned in certain states and regions, while electric resistance pool heaters are more common in certain applications or regions compared to heat pump pool heaters. See chapter 8 for further details.

[r] For example, as shown in chapter 8, the average electric resistance pool heater load in residential applications is 22.9 million Btu per year, which results in an average shipment-weighted energy use of 6,775 kWh/yr (compared to the 10,825 kWh/yr reported in Table 7.4.1).

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CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

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CHAPTER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter describes the U.S. Department of Energy's (DOE's) method for analyzing the economic impacts on individual consumers from potential energy efficiency standards for electric pool heaters (EPHs) and gas-fired pool heaters (GPHs).[a] The effects of standards on individual consumers include a change in purchase price (usually an increase) and a change in operating costs (usually a decrease). This chapter describes three metrics DOE used to determine the impact of standards on individual consumers:

- Life-cycle cost (LCC) is the total consumer expense during the lifetime of an appliance (or other equipment), including purchase expense and operating costs (including energy expenditures). DOE discounts future operating costs to the year of purchase and sums them over the lifetime of the product.
- Payback period (PBP) measures the amount of time it takes a consumer to recover the higher purchase price of a more energy efficient product through lower operating costs. DOE calculates a simple payback period which does not discount operating costs.
- Rebuttable payback period is a special case of the PBP. Whereas LCC is estimated for a range of inputs that reflect real-world conditions, rebuttable payback period is based on laboratory conditions as specified in the DOE test procedure.

DOE conducted the LCC and PBP analysis using a spreadsheet model developed in Microsoft Excel that generated a Monte Carlo simulation to perform the analysis by incorporating uncertainty and variability considerations in certain of the key parameters as discussed further in section 8.1.2.

Inputs to the LCC and PBP analysis of consumer pool heaters are discussed in sections 8.2, 8.3, and 8.4. Results of the LCC and PBP analysis are presented in section 8.5. DOE performed the calculations discussed herein using a Microsoft Excel® spreadsheet that is accessible at https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44.

Details and instructions for using the spreadsheet are provided in appendix 8A of this technical support document (TSD).

[a] For pool heaters installed in commercial applications, the consumer is the business or other entity that pays for the equipment (directly or indirectly) and its energy costs.

8.1.1 General Analysis Approach

Life-cycle cost is calculated using the following equation:

$$LCC = TIC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t}$$

Where:

LCC = life-cycle cost (in dollars),

TIC = total installed cost in dollars,

$\sum$ = sum over the appliance lifetime, from year 1 to year N,

N = lifetime of the appliance in years,

OC_t = operating cost in year t in dollars,

r = discount rate, and

t = year to which operating cost is applied and discounted.

The payback period is the ratio of the increase in total installed cost (i.e., from a less energy efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation results in what is termed a simple payback period, because it does not take into account changes in energy expenses over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent. The equation for PBP is:

$$PBP = \frac{\Delta TIC}{\Delta OC}$$

Eq. 8.2

Where:

ΔTIC = difference in total installed cost between a more energy efficient design and the baseline design, and

ΔOC = difference in annual operating expenses.

Payback periods are expressed in years. Payback periods greater than the life of the product indicate that the increased total installed cost is not recovered through reduced operating expenses.

Recognizing that inputs to the determination of consumer LCC and PBP may be either variable or uncertain, DOE conducted the LCC and PBP analysis by modeling both the uncertainty and variability of the inputs using Monte Carlo simulation and probability distributions for inputs.[b] Appendix 8B provides a detailed explanation of Monte Carlo simulation and the use of probability distributions and discusses the tool used to incorporate these methods.

DOE calculated impacts relative to a case without amended or new energy conservation standards (referred to as the "no-new-standards case"). In the no-new-standards case, some consumers might purchase products with energy efficiency higher than a baseline model. For any given standard level under consideration, consumers expected to purchase a product with efficiency equal to or greater than the considered level in the no-new-standards case would be unaffected by that standard.

DOE calculated the LCC and PBP as if all consumers would purchase the product in the expected initial year of compliance with a new or amended standard. At this time, the expected compliance date of potential energy conservation standards for electric and gas-fired pool heaters manufactured in, or imported into, the United States would be the beginning of 2028. Therefore, DOE conducted the LCC and PBP analysis assuming purchases take place in 2028.

8.1.2 Overview of Analysis Inputs

The LCC analysis uses inputs for establishing (1) the purchase expense, otherwise known as the total installed cost, and (2) the operating costs over the product lifetime.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer cost*: The costs incurred by the manufacturer to produce products that meet current minimum efficiency standards, or another efficiency level designated as the baseline for analysis.
- *Standard-level manufacturer cost*: The manufacturer cost (or cost increase) associated with producing products that meet particular efficiency levels above the baseline.
- *Markups and sales tax*: The markups and sales tax associated with converting the manufacturer cost to a consumer product cost.

[b] A distinct advantage of this type of approach is that DOE can identify the percentage of consumers achieving LCC savings or attaining certain PBP values due to an increased efficiency level, in addition to the average LCC savings or average PBP for that efficiency level.

- *Installation cost*: All costs required to install the product, including labor, overhead, and any miscellaneous materials and parts.

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The product energy consumption is the site energy use associated with operating the product.
- *Energy prices*: The prices consumers pay for energy (e.g., electricity or natural gas).
- *Energy price trends*: The annual rates of change projected for energy prices during the study period.
- *Maintenance costs and repair costs*: Maintenance costs are associated with maintaining the operation of the product. Repair costs are associated with repairing or replacing components that fail.
- *Lifetime*: The age at which the product is retired from service.
- *Discount rates*: The rates at which DOE discounts future expenditures to establish their present value.

The inputs for calculating the PBP are the total installed cost and the first-year operating costs. The inputs to operating costs are the first-year energy cost and the annualized repair cost and the annualized maintenance cost. The PBP uses the same inputs as the LCC analysis, except the PBP does not require energy price trends or discount rates.[c]

Figure 8.1.1 depicts the relationships among the inputs to installed cost and operating cost for calculating a product's LCC and PBP. In the figure, the tan boxes indicate inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate final outputs.

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[c] Because the PBP is a "simple" payback, the required energy cost is only for the year in which a new standard is to take effect—in this case, 2028.

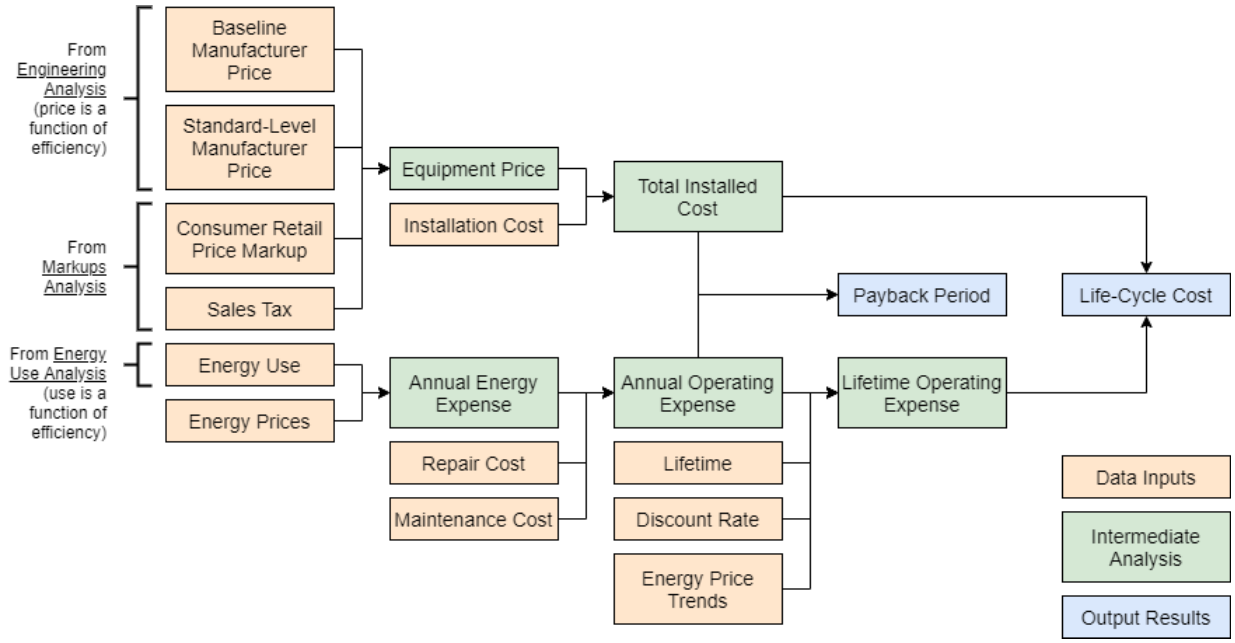

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 provides a summary of inputs, with a greater degree of detail, used in the analysis. As noted earlier, most of the inputs are characterized by probability distributions that capture variability in the input variables.

Table 8.1.1 Summary of Inputs and Key Assumptions Used in the LCC and PBP Analysis

Inputs	Description
Product Price	Derived from the manufacturer production cost (MPC) for each pool heater product class at different input capacities (from the engineering analysis) multiplied by manufacturer, pool wholesaler, pool contractor, pool retailer, pool builder, HVAC wholesaler, HVAC contractor, and/or general contractor markups plus sales tax, as appropriate (from markups analysis, see chapter 6). Used probability distributions to assign different distribution channels for each sampled pool heater. For GPHs, the fraction of low NOx GPHs is taken into account. Used historical data to derive a price scaling index to project product costs in 2028.
Installation Cost	Baseline and incremental installation cost includes installation labor costs and material costs derived from RSMeans's *2021 Residential Cost Data*.[1] The labor and materials costs are assumed to include the appropriate overhead and profits in the contractor's markup and vary by Energy Information Administration's (EIAs) *2015 Residential Energy Consumption Survey* (RECS 2015)[2] and *2012 Commercial Building Energy Consumption Survey* (CBECS 2012)[3] regions.
Annual Energy Use	The total annual energy use is mainly derived by multiplying the number of pool heater hours based on field data by the pool heater input capacity, as well as taking into account standby and off mode energy consumption. Field data variability is primarily based on RECS 2015 and other data sources. See chapter 7.
Baseline Average and Marginal Energy Prices	Baseline electricity prices are based on EIA's Form 861 data for 2021,[4] natural gas prices are based on EIA's Natural Gas Navigator data for 2021,[5] and propane prices are based on EIA's State Energy (SEDS) for 2020.[6] Marginal energy prices for both natural gas and electricity are based on 2012-2021 data from same sources. Energy prices determined for each RECS 2015 and CBECS 2012 regions.
Energy Price Trends	Energy prices were escalated by the EIA's *2022 Annual Energy Outlook* (AEO 2022)[7] forecasts to estimate future energy prices at the census division level.
Maintenance and Repair Cost	Maintenance and repair costs are primarily based on RSMeans's *2021 Facilities Maintenance and Repair Costs*.[8] Both maintenance and repair costs vary for different technologies (non-condensing gas-fired pool heaters compared to condensing gas-fired pool heaters and electric resistance pool heaters compared to heat pump pool heaters). Repair costs are based on costs of major repair (such as heat exchanger, electric resistance element, ignition, gas valve, compressor, etc.).
Product Lifetime	Used Weibull probability distribution of lifetimes developed for pool heaters using shipments model (see chapter 9).
Discount Rate	The residential discount rate approach involves identifying all possible debt or asset classes that might be used to purchase the considered appliances, or might be affected indirectly and the primary data source was the Federal Reserve Board's 1995-2019 Survey of Consumer Finances (SCF).[9] The commercial discount rates are

	calculated as the weighted average cost of capital for businesses purchasing pool heaters, and the primary data source was Damodaran Online.[10] Both residential and commercial discount rates are presented to vary by income bins and business activity, respectively.
Dollar Year	DOE expressed all costs in 2021$.
Compliance Date	2028 (5 years after expected publication of the final rule).

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in section 8.2 and 8.3.

In addition, to accurately estimate the share of consumers that would be affected by a potential energy conservation standard at a particular efficiency level, DOE's LCC analysis considered the projected distribution (market shares) of product efficiencies under the no-new-standards case (*i.e.*, the case without amended or new energy conservation standards). See section 8.4.

8.1.3 Sample of Pool Heater Users

The LCC and PBP calculations detailed here are for a representative sample of individual electric and gas-fired pool heater users. By developing consumer samples, DOE accounted for the variability in the LCC and PBP inputs associated with a range of consumers.

As described in chapter 7 of this TSD, DOE used primarily EIA's *2015 Residential Energy Consumption Survey* (RECS 2015) and *2012 Commercial Buildings Energy Consumption Survey* (CBECS 2012) to develop the pool heater samples for swimming pools and spas in residential and commercial applications that use electric and gas-fired pool heaters. The RECS 2015 consists of 5,686 housing units and is representative of the household population of the United States, while CBECS 2012 consists of 6,720 commercial buildings and is representative of commercial buildings throughout the United States. DOE assigned unique inputs to each pool heater in the sample. The large pool heater sample considered in the analysis provides wide ranges of inputs (including product prices, installation costs, annual energy use, energy prices, maintenance and repair costs, and discount rates).

Appendix 7A presents the variables used and their definitions, as well as further information about the derivation of the household sample.

8.2 TOTAL INSTALLED COST INPUTS

DOE used the following equation to define the total installed cost.

$$TIC = CPC + IC$$

Eq. 8.3

Where:

TIC = total installed cost,

CPC = consumer purchase cost, and

IC = installation cost.

The consumer purchase cost is equal to the manufacturer cost (including shipping cost) multiplied by markups, and where applicable, sales tax. The cost varies based on the distribution channel through which the consumer purchases the product. The installation cost represents all costs to the consumer for installing the product, including labor, overhead, and any miscellaneous materials and parts. The installation cost may vary by efficiency level.

The rest of this section provides information about each of the inputs that DOE used to calculate the total installed cost of consumer pool heater products.

8.2.4 Consumer Purchase Cost

DOE used the following equation to calculate the consumer purchase cost.

$$CPC = (MSP_{BASE} \times MU_{BASE} + \Delta MSP \times MU_{INCR}) \times LR$$

Eq. 8.4

Where:

CPC = consumer purchase cost,

MSP = manufacturer selling price (MSP)

*MSP*BASE = manufacturer selling price (MSP) for the baseline design (EL 0),

*MU*BASE = total baseline markup (including sales tax, but not including manufacturer markup),

ΔMSP = difference in MSP between a more energy efficient design and the baseline design, and

*MU*INCR = total incremental markup (including sales tax, but not including manufacturer markup), and

LR = learning rate for 2028.

$$MSP_{BASE} = MPC_{BASE} \times MU_{MFR} + SC_{BASE}$$

Eq. 8.5

$$\Delta MSP = \Delta MPC \times MU_{MFR} + \Delta SC$$

Eq. 8.6

Where:

*MPC*BASE = manufacturer product cost (MPC) for the baseline design (EL 0),

*MU*MFR = manufacturer markup,

SC = shipping costs for the baseline design,

ΔMPC = difference in MPC between a more energy efficient design and the baseline design, and

ΔSC = difference in shipping costs between a more energy efficient design and the baseline design.

The remainder of this section provides information about the variables that DOE used to calculate the consumer purchase cost for EPHs and GPHs.

8.2.4.1 Manufacturer Costs

DOE developed manufacturer product costs (MPCs) for pool heaters as described in chapter 5 of this TSD. The manufacturer costs at each efficiency level for all the product classes are shown in Table 8.2.1. Note that the MPCs developed in chapter 5 are at the representative output capacity by output capacity for EPHs (110 kBtu/h) and representative input capacity for GPHs (250 kBtu/h). In addition, many 82-percent thermal efficiency (EL 0 and EL 1) gas-fired pool heaters without low-NO_X burners that are currently available do not meet low-NO_X criteria in California, Utah, and Texas.[d] Thus, DOE included

[d] Low-NOx gas-fired pool heaters account for 11 percent of gas-fired pool heaters at EL 0 and 59 percent of pool heaters at EL 1.

the additional cost of a low-NO_X burner to all gas-fired pool heaters installed in certain California,[e] Utah,[f] or Texas[g] locations and applications. DOE assigned a fraction of installations outside these two regions the low-NO_X burner cost adder, since the models are so widespread (for example, most Hayward and Pentair models are low-NO_X).[16] Chapter 5 contains additional details about DOE's cost assumptions and estimates.

Table 8.2.1 Manufacturer Production Cost for Electric and Gas-fired Pool Heaters by Efficiency

Product Class	Representative TEi %	Manufacturer Production Cost *2021$*	Incremental Cost *2021$*
Electric Pool Heaters	99%	$1,028.0	-
	387%	$1,248.1	$220.0
	483%	$1,304.8	$276.8
	534%	$1,354.6	$326.6
	551%	$1,427.0	$399.0
	595%	$1,523.4	$495.4
Gas-fired Pool Heaters	69.7%*	$781.7	-
	81.3%*	$788.0	$6.3
	83.3%	$969.3	$187.6
	94.7%	$1,348.8	$567.1

* Not including low-NO_X adder of $51.21 in 2021$.

8.2.4.2 Shipping Costs

DOE developed shipping costs for pool heaters as described in chapter 5 of this TSD. Manufacturers of consumer pool heaters typically pay for freight to the first step in the distribution chain. Freight is not a manufacturing cost, but because it is a substantial cost incurred by the

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[e] Low-NOx gas-fired pool heaters with a rated heat input capacity less than or equal to 2,000,000 Btu/h are required in South Coast Air Quality Management District (SCAQMD)[11] and San Joaquin Valley Air Pollution Control District (SJAPCD).[12] Low NOx gas-fired pool heaters with a rated heat input capacity 400,001 to 2,000,000 Btu/h are required in Bay Area Air Quality Management District (BAAQMD). [13]
[f] Low-NOx gas-fired pool heaters with a rated heat input capacity less than 2,000,000 Btu/h.[14]
[g] Low NOx gas-fired pool heater with a rated heat input capacity less than or equal to 2,000,000 Btu/h are required (except for units installed in single-family residences, used exclusively to heat swimming pools and hot tubs).[15]

manufacturer, DOE accounted for shipping costs separately from the non-production costs that comprise the manufacturer markup. The shipping costs at each efficiency level for all the product classes are shown in Table 8.2.2. Chapter 5 contains additional details about DOE's cost assumptions and estimates.

Table 8.2.2 Shipping Cost for Electric and Gas-fired Pool Heaters by Efficiency

Product Class	Representative Integrated Thermal Efficiency (TE_i) %	Shipping Cost	Incremental Cost
		2021$	***2021$***
Electric Pool Heaters	99%	$12.0	-
	387%	$110.6	$98.6
	483%	$110.6	$98.6
	534%	$110.6	$98.6
	551%	$110.6	$98.6
	595%	$110.6	$98.6
Gas-fired Pool Heaters	69.7%	$59.9	-
	81.3%	$59.9	0
	83.3%	$49.2	(10.7)
	94.7%	$73.8	13.9

8.2.4.3 Markups

For a given distribution channel, the overall markup is the value determined by multiplying all the associated markups and the applicable sales tax together to arrive at a single overall distribution chain markup value. Because there are baseline and incremental markups associated with the various market participants, the overall markup is also divided into a baseline markup (*i.e.*, a markup used to convert the baseline manufacturer price into a consumer price) and an incremental markup (*i.e.*, a markup used to convert a standard-compliant manufacturer cost increase due to an efficiency increase into an incremental consumer price). Refer to chapter 6 of this TSD for details. Table 8.2.3 shows the overall baseline and incremental markups for electric and gas-fired pool heaters.

Table 8.2.3 Summary of Overall Markups for Pool Heaters

Product Class	Baseline Markup	Incremental Markup
Electric Pool Heaters	2.67	2.01
Gas-Fired Pool Heaters	2.78	2.09

8.2.4.4 Application of Learning Rate for Product Prices

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that an assumption of constant real prices may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may, in fact, trend downward over time according to "learning" or "experience" curves. Desroches *et al*. (2013) summarizes the data and literature that is relevant to price projections for selected appliances and equipment.[17] The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[h]

In light of these data and DOE's aim to improve the accuracy and robustness of its analyses, DOE decided to assess future costs by incorporating a price trend over time, consistent with the analysis in the available literature. DOE used this approach to project future prices of EPHs and GPHs in the rulemaking analysis.

For electric pool heaters, DOE considered heat pump pool heaters as a design option to increase efficiency. The technology used in electric resistance pool heaters (ERPHs) has been widely applied and has already reached maturity, whereas heat pump pool heaters (HPPHs) use a more innovative technology that may be undergoing a much different experience curve than electric resistance pool heaters. Hence, DOE developed separate product price projections for baseline electric resistance pool heaters and heat pump pool heaters with higher efficiencies.

DOE obtained historical distributor prices for EPHs, HPPHs, and GPHs at different ratings spanning the time period 2003-2021 from the 2022 Pkdata.[19] DOE first averaged the prices across ratings within a product type to come up with an average price series for each product type. Then, the inflation-adjusted prices were calculated by dividing the average prices by the implicit price deflator for Gross Domestic Product (see Figure 8.2.1).

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[h] In addition to Desroches (2013), see Weiss, et al (2010). [18]

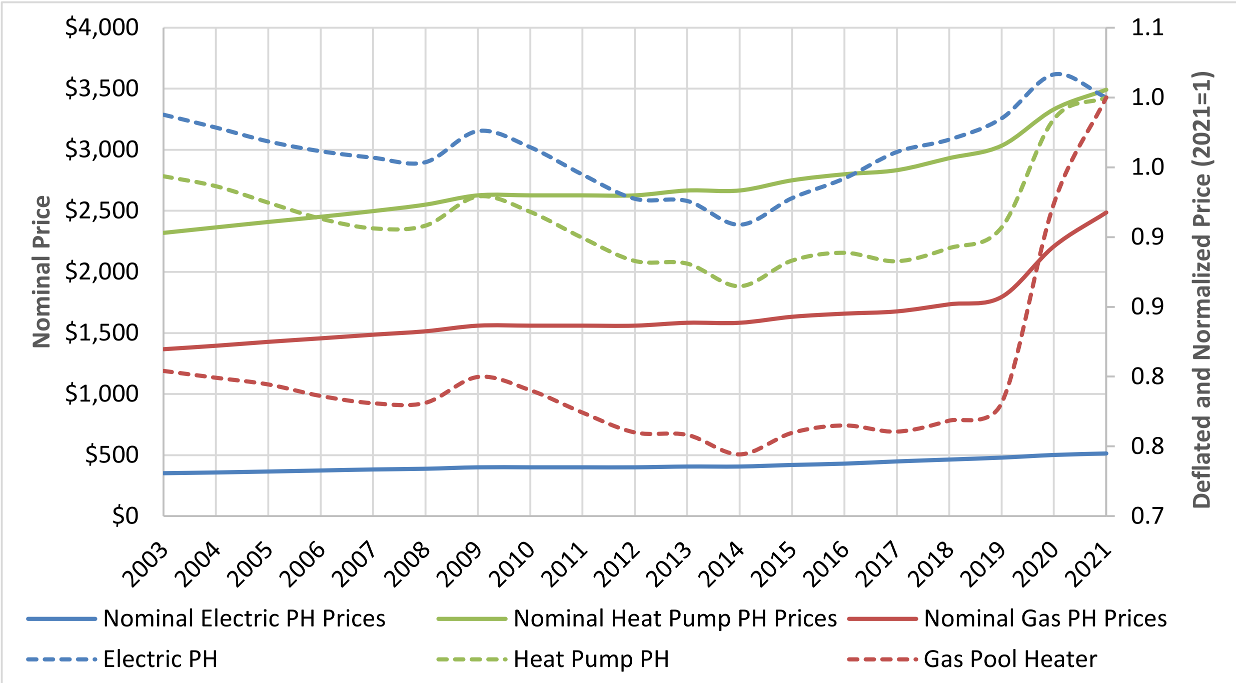

Figure 8.2.1 Historical Nominal and Deflated Prices for Pool Heaters from 2003 to 2021

Due to the relatively limited historical pool heater prices, DOE used the inflation-adjusted prices to fit an exponential model with *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

Eq. 8.7

Where:

Y = the deflated pool heater prices,

a = the constant,

b = the slope parameter of the time variable, and

X = the time variable.

To estimate these exponential parameters for each product type, a least-square fit was performed on the inflation-adjusted pool heater prices versus *year* from 2003 to 2021 for ERPHs, HPPHs and GPHs separately. All three regressions performed as an exponential trend line fit result a moderate fit to the data. DOE then derived a price factor index, with 2021 equal to 1, to project prices in each future year in the analysis period considered in the NIA. The index value in a given year is a function of the exponential parameter and *year*. Based on this fitting, DOE used a constant trend as the reference, since for all pool heater designs there is a decreasing trend until 2014 and then a slight increasing trend from 2014 to 2019 and more pronounced increase for 2020 to 2021 likely due to COVID-19 pandemic and supply chain issues. The no price trend scenario assumes zero percent learning rate for all products, implying constant real prices over the entire forecast period. See Appendix 8C for more details.

8.2.4.5 Total Consumer Price

To calculate consumer product costs, DOE multiplied the MPCs and shipping costs developed in the engineering analysis by the markups described previously (along with sales taxes), as well as the learning rate price index in 2028.[i] DOE derived the consumer product price for the baseline product by taking the product of the baseline manufacturer cost and the baseline overall markup (including the sales tax). For each efficiency level above the baseline, DOE derived the consumer product price by taking baseline product consumer price and adding to it the product of the incremental manufacturer cost and the incremental overall markup (including the sales tax). Markups and sales tax can all take on a variety of values depending on distribution channel type and installation location, so the resulting consumer price for a particular efficiency level is represented by a distribution of values.

Table 8.2.4 presents the average consumer product price for each pool heater product class at each efficiency level examined in 2028.

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[i] DOE multiplied the MPC by the manufacturer markup first and then added shipping costs, to calculate the manufacturer selling price (MSP), which is then multiplied by the remaining markups and sales taxes.

Table 8.2.4 Average Consumer Price for Electric and Gas-fired Pool Heaters in 2028

Product Class	Representative TE_i %	Average Consumer Price 2021$	Incremental Cost 2021$
Electric Pool Heater	99%	2,768	--
	387%	3,354	586
	483%	3,468	700
	534%	3,568	800
	551%	3,714	946
	595%	3,908	1,140
Gas-fired Pool Heater	69.7%	2,437	--
	81.3%	2,450	13
	83.3%	2,700	263
	94.7%	3,530	1,093

8.2.5 Installation Cost

The installation cost is the cost to the consumer of installing a pool heater. Installation cost includes labor, overhead, and any miscellaneous materials and parts needed to install the product. DOE estimated all the installation costs associated with fitting a consumer pool heater in a new housing unit, as a replacement for an existing pool heater, or in an existing pool without a pool heater (new owners). This included the delivery of the new pool heater, removal of the existing pool heater, setting, connecting, and start-up, water pipe connections, and electrical requirements. Additional costs required to install equipment at various efficiency levels could include electrical modifications.

DOE estimated the installation costs at each considered efficiency level using a variety of sources, including RSMeans 2021 *Residential Cost Data*, manufacturer literature, and information from expert consultants.[20,21] DOE assumed that the installation costs would be for a representative unit (110 kBtu/h output capacity for electric pool heaters and 250 kBtu/h input capacity for gas-fired pool heaters at DOE test procedure conditions). DOE's analysis of installation costs accounted for regional differences in labor costs by using RS Means regional cost factors.

For new pool heater owners (including owners of new swimming pools and owners of existing swimming pools), DOE included the installation costs associated with the electrical requirements for all pool heater types. DOE assumed that the ERPHs would have higher electrical connection installation costs in comparison with the electrical requirements for the HPPHs (since ERPHs require higher amperage compared to HPPHs). DOE assumed that all GPHs would require a 120V outlet connection and added the cost of new gas piping for installing a natural gas or propane pool heater. In addition, DOE added installation cost associated with flue venting requirements including adding a flue vent stack for some non-condensing outdoor installations in high wind areas and appropriate flue venting for GPHs installed indoors (which is assumed to be less than 1 percent of the residential market and about one-third of commercial market). For GPHs with condensing design (EL 3), the incremental installation cost includes the cost of adding a condensate drain piping that goes from the GPH to a P-trap device[j] located at the sewer line entrance.

For EPH replacements, DOE considered that the installation costs would be the same for all efficiency levels (because the old consumer pool heater already has adequate electrical service and water piping for the new pool heater), with the exception of electric pool heaters installed indoors. For replacements in indoor installations, DOE assumed that they would be all electrical resistance and that replacement with a heat pump pool heater would add a significant cost to run water piping and an electrical connection to an outdoor location adequate to the installation of the heat pump pool heater.

For GPH replacements, DOE assumed that old consumer pool heater would already have adequate electrical service, gas piping, and water piping for the new pool heater. Similar to the new pool heater owners, DOE added installation cost associated with flue venting requirements including adding a flue vent stack for some non-condensing outdoor installations in high wind areas and appropriate changes to the flue venting for GPHs installed indoors (which is assumed to be less than 1 percent of the residential market and about one-third of commercial market). For GPHs with condensing design (EL 3), the incremental installation cost includes the cost of adding a condensate drain piping that goes from the GPH to a P-trap device located at the sewer line entrance and adding new PVC venting when GPH is installed indoors.

Table 8.2.5 shows the average and incremental installation cost for each pool heater product class at each energy efficiency level. For a detailed discussion of the development of installation costs, see appendix 8D.

Table 8.2.5 Average and Incremental Installation Cost for Pool Heaters

[j] A "P-trap" is required by many city codes. It helps to isolate the condensate from back-flowing into the pool water and prevents the sewer gas from back-flowing.

Product Class	Representative TE_i %	Average Total Installed Cost 2021$	Incremental Cost 2021$
Electric Pool Heater	99%	905	--
	387%	764	(141)
	483%	758	(147)
	534%	758	(147)
	551%	758	(147)
	595%	758	(147)
Gas-fired Pool Heater	69.7%	1,028	--
	81.3%	1,028	0
	83.3%	1,024	(5)
	94.7%	1,125	96

Note: Parentheses indicate negative values.

8.2.6 Total Installed Cost

The total installed cost is the sum of the product price and the installation cost. MSPs, markups, and sales taxes all can take on a variety of values, depending on location, so the resulting total installed cost for a particular efficiency level will not be a single-point value, but rather a distribution of values. Table 8.2.6 presents the average total installed cost for each pool heater product class at each efficiency level examined.

Table 8.2.6 Average Total Installed Cost for Pool Heaters

Product Class	Representative TE_i %	Average Total Installed Cost 2021$	Incremental Cost 2021$
Electric Pool Heater	99%	3,673	--
	387%	4,117	444
	483%	4,226	553
	534%	4,326	653
	551%	4,472	799
	595%	4,666	993
Gas-fired Pool Heater	69.7%	3,465	--
	81.3%	3,479	13
	83.3%	3,723	258
	94.7%	4,655	1,189

8.3 OPERATING COST INPUTS

DOE defined operating cost (OC) using the following equation:

$$OC_t = EC_t + RC_t + MC_t$$

Eq. 8.8

Where:

OCt = operating cost in year t ($),

ECt = energy cost associated with operating the product in year t ($),

RCt = repair cost associated with component failure in year t ($),

MCt = maintenance cost for maintaining product operation in year t ($), and

t = year to which operating cost is applied and discounted.

DOE defined the energy cost using the following equation:

$$EC_t = AEC_t \times EP_t$$

Eq. 8.9

Where:

*AEC*t = annual energy consumption at the site in year *t*, and

*EP*t = energy price in year *t*.

The annual energy costs of the equipment are computed from energy consumption per unit for the baseline and the considered efficiency levels, combined with the energy prices. Product lifetime, discount rate, and compliance date of the standard are required for determining the operating cost and for establishing the present value of the operating cost (as shown in Equation 8.1). The remainder of this section provides information about the variables that DOE used to calculate the operating cost for EPHs and GPHs.

8.3.1 Annual Energy Use Savings

For each product class, DOE calculated the annual energy use (AEC) for each sample pool heater at each efficiency level, as described in chapter 7 of this TSD. Tables in chapter 7 provide the average annual energy consumption by efficiency level for EPHs and GPHs.

8.3.1.1 Rebound Effect

Higher-efficiency consumer pool heaters reduce the operating costs for a consumer, which can lead to greater use of the consumer pool heater. A direct rebound effect occurs when a product that is made more efficient is used more intensively, such that the expected energy savings from the efficiency improvement may not fully materialize. At the same time, consumers benefit from increased utilization of products due to rebound. Overall consumer welfare (taking into account additional costs and benefits) is generally understood to increase from rebound. DOE did not find any data on the rebound effect that is specific to consumer pool heaters. Given the uncertainty and lack of data specific to pool heaters, DOE does not include the rebound effect in the LCC analysis for this final rule. DOE does include rebound in the NIA for a conservative estimate of national energy savings. See chapter 10 for further discussion about the rebound effect and the impact on energy use savings.

8.3.2 Energy Prices

DOE derived average and marginal monthly energy prices for each of the RECS 2015 and CBECS 2012 regions in the United States using the latest data from EIA and monthly energy price factors that it developed. The LCC sampling process then assigned an appropriate energy price to each pool heater in the sample, depending on its type (residential or commercial) and its location. Because marginal prices more accurately captures the incremental costs or savings associated with a change in energy use from higher efficiency, it provides a better representation of incremental change in consumer costs than average energy prices. Therefore, DOE applied average energy prices for the energy use of the product purchased in the no-new-standards case, and marginal electricity prices for the incremental change in energy use associated with the other efficiency levels considered. The following equation summarizes DOE's approach of calculating the energy cost per year using monthly average and marginal energy prices together with monthly energy consumption for each sampled pool heater:

$$EC_t = \left[\sum_m MEC_{BASE,t,m} \times MEP_{AVG,t,m} + \sum_m \Delta MEC_{t,m} \times MEP_{MAR,t,m} \times MEPF_{MAR,t,m}\right] \times EPT_t$$

Eq. 8.10

Where:

$MEC_{BASE,t,m}$ = monthly energy consumption at the site for baseline design in the month *m* of year *t*,

$MEP_{AVG,t,m}$ = monthly average energy price in the month *m* of year *t*,

$\Delta MEC_{t,m}$ = change in monthly energy consumption from higher efficiency design in the month *m* of year *t*,

$MEP_{MAR,t,m}$ = monthly average marginal energy price in the month *m* of year *t*,

$MEPF_{MAR,t,m}$ = monthly marginal energy price factor for the month *m* of year *t*, and

EPT_t = energy price trend in year *t*.

8.3.2.1 Base Year Energy Prices

To derive average monthly energy prices, DOE first derived base year (2021) average annual energy prices. DOE then multiplied the base year energy prices by monthly price factors for each energy source to derive energy prices for each month. To estimate the monthly marginal energy prices (which are used to determine the cost to the consumer of the change in energy consumed), DOE estimated seasonal marginal price factors that were then used to adjust the monthly average energy prices.

Derivation of Average Energy Prices for the Base Year

DOE first derived base year (2021) average annual residential and commercial electricity, natural gas, and LPG prices for each State using the most recent historical data from EIA. For electricity prices, DOE used 2021 data from EIA's Form 861M. [4] For natural gas prices, DOE used 2021 data from EIA's Natural Gas Navigator.[5] For LPG prices, DOE used 2020 data from EIA's State Energy Consumption, Price, and Expenditure Estimates (SEDS) [6] and escalated the prices to 2021 using EIA's *2022 Annual Energy Outlook* (AEO 2022).[7]

Derivation of Average Monthly Energy Factors

To determine monthly prices for use in the analysis for each State, DOE developed monthly energy price factors for each energy source based on long-term price data from the same sources above. For electricity and natural gas prices it used the last 20 years of EIA's Form 861M and Natural Gas Navigator state level data (2002-2021) and for LPG it used EIA's SEDS regional data from 1995 to 2009 data (which is the only historical data available). See appendix 8E for a description of the method.

Derivation of Seasonal Marginal Price Factors

Monthly electricity and natural gas prices were adjusted using seasonal marginal price factors to determine monthly marginal electricity and natural gas prices. For electricity and natural gas, DOE used EIA state level data from the last 10 years (2012 to 2021) to estimate marginal price as the slope of the rate of change in the energy costs versus change in energy consumption. Since marginal prices change significantly by season, DOE calculated separate winter and non-winter marginal prices separately. The seasonal marginal price factors are then calculated as the ratio of the marginal price to the average for each State and residential and commercial market sectors. For LPG, DOE estimated that average and marginal energy prices are the same. For a detailed discussion of the development of marginal energy price factors and for a comparison to other data and methods, see appendix 8E.

Table 8.3.1 and Table 8.3.2 show residential marginal monthly natural gas and electricity prices. Average LPG prices and commercial prices are shown in appendix 8E.

Table 8.3.1 Residential Marginal Monthly Natural Gas Prices for 2021 (2021$/MMBtu)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	12.11	12.05	12.44	10.54	11.99	13.18	13.82	13.95	13.87	13.43	14.89	12.88
Alaska	9.88	9.98	9.84	8.57	9.13	9.74	10.49	10.30	9.37	8.70	9.89	10.26
Arizona	10.06	10.65	11.39	9.87	11.00	12.21	13.30	13.62	13.24	11.80	12.43	10.65
Arkansas	10.16	10.10	10.58	7.78	8.67	10.73	11.66	12.14	11.79	10.59	12.24	10.74
California	17.16	16.86	16.22	12.67	13.43	14.30	14.55	14.49	14.32	14.34	16.90	17.31
Colorado	6.82	6.85	7.23	5.31	6.16	7.81	8.63	8.71	7.67	5.78	7.29	6.96
Connecticut	12.68	12.76	13.02	10.64	11.92	13.57	14.91	15.43	15.13	12.90	13.99	13.18
Delaware	10.21	10.46	10.96	7.97	9.22	11.05	12.31	12.96	12.51	11.02	11.88	10.61
Dist. of Columbia	12.48	12.22	12.65	10.22	11.64	12.83	13.99	13.75	13.62	11.99	13.85	12.62
Florida	12.75	12.77	13.60	12.26	12.70	14.45	15.29	15.65	15.31	15.09	16.08	14.04
Georgia	10.67	11.30	11.96	14.03	17.22	20.27	21.39	21.77	21.61	17.57	12.88	11.54
Hawaii	35.02	36.19	37.03	54.04	55.19	55.50	56.10	56.46	56.26	56.20	37.80	36.96
Idaho	6.40	6.42	6.59	5.94	6.20	6.64	7.00	7.14	6.65	6.05	6.40	6.32
Illinois	8.10	8.13	8.71	5.59	6.87	7.94	9.69	9.84	9.10	6.49	9.20	8.51
Indiana	7.29	7.39	8.23	5.82	6.77	8.27	9.25	9.10	7.65	5.49	7.46	7.31
Iowa	7.73	7.86	8.63	5.61	6.61	8.58	9.97	10.39	9.90	7.28	9.10	8.03
Kansas	8.85	9.03	9.54	6.20	7.39	9.16	9.93	10.54	9.80	7.59	9.89	9.11
Kentucky	9.07	9.08	9.50	5.85	7.33	9.29	10.03	10.33	9.83	7.23	10.23	9.56
Louisiana	8.66	8.68	9.31	7.27	7.87	8.70	9.56	9.71	9.42	9.24	10.63	8.90
Maine	15.20	15.70	15.57	12.70	12.64	13.42	15.02	15.57	14.75	13.10	15.42	15.83
Maryland	10.62	10.46	10.87	8.86	10.51	12.29	13.15	13.42	12.92	9.67	11.62	11.10
Massachusetts	15.67	15.58	15.60	14.74	14.85	14.65	16.10	16.78	16.23	13.95	15.66	16.20
Michigan	7.58	7.65	7.85	6.47	7.40	8.72	9.50	9.79	8.96	7.09	8.12	7.85
Minnesota	8.78	8.80	9.01	6.15	7.02	8.36	9.00	8.82	8.28	6.55	8.71	9.03
Mississippi	9.82	9.90	10.92	8.64	9.88	11.08	10.97	11.25	11.29	10.72	12.14	10.74
Missouri	6.90	6.89	7.27	5.67	6.92	9.15	10.70	11.20	10.48	8.61	9.06	7.60
Montana	7.67	7.74	7.79	6.92	7.27	8.22	9.45	10.12	9.17	7.45	8.00	7.78
Nebraska	7.88	8.02	8.21	5.47	6.26	7.62	9.10	9.59	9.28	7.71	9.61	8.57

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Nevada	6.87	7.06	7.40	5.98	6.51	6.97	7.62	7.92	7.59	6.89	8.06	7.10
New Hampshire	14.99	14.86	14.93	11.77	12.23	13.15	15.65	16.61	16.10	13.76	15.88	16.04
New Jersey	9.15	9.09	9.11	7.27	8.00	8.79	9.26	9.54	9.29	8.50	9.87	9.37
New Mexico	7.33	7.32	7.51	4.68	5.36	6.58	7.34	7.17	7.46	6.62	8.81	7.41
New York	10.06	9.91	10.18	7.89	8.94	10.65	11.58	11.78	11.49	9.47	11.47	10.49
North Carolina	9.79	9.88	10.24	8.49	10.44	12.25	13.10	12.89	12.77	10.52	11.05	10.66
North Dakota	6.25	6.30	6.57	3.79	4.58	6.45	7.27	7.22	6.63	3.83	6.80	6.47
Ohio	7.59	7.68	7.86	4.14	5.17	6.74	8.10	8.48	7.90	5.54	8.79	8.05
Oklahoma	6.68	6.84	7.21	5.53	7.01	8.84	10.21	11.11	10.64	9.42	9.94	7.17
Oregon	12.64	12.58	12.89	8.93	9.56	10.23	11.08	11.81	10.98	9.49	12.44	12.59
Pennsylvania	9.62	9.70	9.92	7.28	8.33	10.20	11.41	11.82	11.18	8.89	10.58	9.95
Rhode Island	12.12	12.23	12.47	11.82	12.76	14.00	15.32	15.92	15.67	14.18	13.64	12.71
South Carolina	8.96	9.15	9.59	6.90	8.71	9.47	10.64	10.57	10.40	8.46	10.14	9.08
South Dakota	8.07	8.21	8.78	6.64	7.15	9.01	10.66	11.05	10.35	7.52	8.88	8.27
Tennessee	8.46	8.46	8.32	5.84	6.94	8.26	9.04	9.04	8.98	7.98	10.10	8.44
Texas	7.86	8.26	8.96	7.20	8.66	9.75	10.45	11.11	10.83	9.71	11.34	8.73
Utah	8.11	8.28	8.34	7.24	7.11	7.83	8.54	8.90	8.70	7.74	8.34	8.46
Vermont	11.29	11.07	11.30	8.52	9.39	11.18	12.84	13.50	13.03	11.05	12.65	11.81
Virginia	9.90	9.91	10.00	7.59	8.71	10.25	11.91	11.80	11.62	8.92	11.07	10.46
Washington	10.08	10.12	10.24	8.82	9.08	10.39	11.21	11.62	10.76	9.24	10.45	10.14
West Virginia	8.77	8.84	8.95	7.21	8.40	9.97	11.63	11.83	10.57	8.12	9.41	9.05
Wisconsin	9.45	9.40	9.92	6.43	7.43	8.55	9.80	10.02	9.11	6.64	9.99	9.66
Wyoming	7.54	7.64	7.78	6.30	6.81	8.26	10.91	11.57	10.39	7.77	8.33	7.75
United States	9.81	9.85	10.18	7.18	8.20	9.55	10.38	10.65	10.15	8.29	10.81	10.22

Table 8.3.2 Residential Marginal Monthly Electricity Prices for 2021 (2021$/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.099	0.103	0.105	0.132	0.129	0.132	0.131	0.132	0.132	0.132	0.107	0.101
Alaska	0.196	0.197	0.202	0.182	0.187	0.189	0.193	0.190	0.186	0.187	0.207	0.204
Arizona	0.098	0.101	0.103	0.126	0.136	0.134	0.134	0.133	0.133	0.131	0.103	0.102
Arkansas	0.080	0.084	0.085	0.118	0.120	0.123	0.123	0.123	0.124	0.118	0.090	0.084
California	0.220	0.217	0.214	0.264	0.290	0.301	0.305	0.306	0.298	0.263	0.223	0.223
Colorado	0.109	0.111	0.112	0.148	0.150	0.155	0.156	0.156	0.157	0.151	0.116	0.113
Connecticut	0.186	0.192	0.193	0.194	0.196	0.193	0.189	0.189	0.192	0.194	0.192	0.187
Delaware	0.091	0.092	0.094	0.103	0.109	0.108	0.104	0.105	0.107	0.110	0.103	0.096
District of Columbia	0.101	0.103	0.103	0.113	0.117	0.121	0.120	0.121	0.120	0.118	0.106	0.105
Florida	0.123	0.125	0.124	0.126	0.123	0.125	0.125	0.126	0.127	0.126	0.128	0.125
Georgia	0.099	0.102	0.105	0.146	0.150	0.159	0.161	0.162	0.157	0.148	0.104	0.099
Hawaii	0.297	0.299	0.300	0.289	0.290	0.294	0.295	0.296	0.296	0.298	0.313	0.312
Idaho	0.098	0.098	0.098	0.114	0.119	0.125	0.126	0.125	0.119	0.121	0.101	0.100
Illinois	0.084	0.087	0.090	0.116	0.119	0.115	0.113	0.113	0.115	0.118	0.093	0.086
Indiana	0.094	0.097	0.101	0.126	0.127	0.122	0.120	0.121	0.124	0.129	0.107	0.100
Iowa	0.091	0.093	0.096	0.162	0.169	0.176	0.180	0.182	0.173	0.164	0.098	0.094
Kansas	0.089	0.094	0.097	0.131	0.133	0.134	0.135	0.135	0.133	0.130	0.098	0.093
Kentucky	0.088	0.090	0.091	0.110	0.111	0.109	0.108	0.109	0.109	0.113	0.097	0.094
Louisiana	0.079	0.081	0.084	0.109	0.113	0.112	0.113	0.114	0.114	0.115	0.085	0.083
Maine	0.158	0.160	0.161	0.161	0.163	0.163	0.161	0.162	0.164	0.163	0.162	0.159
Maryland	0.115	0.115	0.116	0.119	0.123	0.129	0.126	0.126	0.127	0.126	0.120	0.119
Massachusetts	0.239	0.241	0.241	0.208	0.207	0.204	0.200	0.203	0.209	0.204	0.237	0.244
Michigan	0.152	0.153	0.153	0.182	0.185	0.191	0.192	0.193	0.189	0.186	0.157	0.157
Minnesota	0.109	0.110	0.111	0.145	0.150	0.158	0.158	0.157	0.155	0.151	0.114	0.111
Mississippi	0.085	0.087	0.091	0.108	0.109	0.108	0.106	0.106	0.105	0.106	0.094	0.089
Missouri	0.072	0.073	0.077	0.140	0.158	0.167	0.166	0.165	0.150	0.142	0.081	0.076
Montana	0.093	0.094	0.095	0.100	0.104	0.107	0.108	0.108	0.109	0.106	0.099	0.096
Nebraska	0.065	0.068	0.071	0.124	0.130	0.142	0.145	0.145	0.146	0.130	0.075	0.069
Nevada	0.094	0.096	0.097	0.110	0.109	0.105	0.104	0.104	0.106	0.110	0.100	0.096

New Hampshire	0.178	0.181	0.182	0.170	0.172	0.169	0.166	0.165	0.169	0.173	0.185	0.183
New Jersey	0.158	0.160	0.160	0.167	0.169	0.177	0.182	0.182	0.178	0.167	0.160	0.161
New Mexico	0.116	0.118	0.118	0.153	0.155	0.164	0.166	0.168	0.164	0.163	0.120	0.118
New York	0.171	0.175	0.173	0.199	0.206	0.213	0.214	0.213	0.215	0.211	0.180	0.175
North Carolina	0.088	0.091	0.093	0.111	0.109	0.107	0.109	0.110	0.112	0.115	0.095	0.090
North Dakota	0.068	0.070	0.073	0.086	0.094	0.102	0.100	0.100	0.102	0.093	0.077	0.072
Ohio	0.098	0.100	0.102	0.134	0.138	0.140	0.139	0.139	0.135	0.135	0.107	0.102
Oklahoma	0.065	0.076	0.073	0.116	0.113	0.114	0.114	0.116	0.122	0.120	0.075	0.067
Oregon	0.103	0.104	0.104	0.109	0.111	0.112	0.113	0.112	0.113	0.112	0.107	0.105
Pennsylvania	0.115	0.117	0.118	0.134	0.138	0.140	0.139	0.139	0.138	0.138	0.122	0.119
Rhode Island	0.228	0.234	0.229	0.191	0.189	0.186	0.182	0.191	0.198	0.192	0.232	0.239
South Carolina	0.104	0.107	0.108	0.130	0.128	0.128	0.127	0.127	0.129	0.130	0.113	0.107
South Dakota	0.087	0.089	0.090	0.119	0.127	0.131	0.130	0.129	0.132	0.129	0.096	0.091
Tennessee	0.092	0.092	0.094	0.110	0.111	0.110	0.109	0.109	0.108	0.112	0.100	0.097
Texas	0.099	0.101	0.103	0.118	0.119	0.121	0.120	0.120	0.120	0.119	0.105	0.103
Utah	0.096	0.096	0.096	0.116	0.121	0.125	0.128	0.128	0.124	0.118	0.098	0.097
Vermont	0.157	0.159	0.160	0.176	0.177	0.178	0.175	0.175	0.177	0.181	0.167	0.162
Virginia	0.093	0.095	0.098	0.127	0.130	0.133	0.133	0.133	0.131	0.129	0.101	0.096
Washington	0.093	0.094	0.094	0.088	0.089	0.090	0.090	0.090	0.091	0.090	0.097	0.096
West Virginia	0.095	0.096	0.099	0.113	0.116	0.114	0.112	0.113	0.115	0.118	0.103	0.098
Wisconsin	0.118	0.120	0.121	0.139	0.143	0.143	0.141	0.141	0.144	0.142	0.124	0.120
Wyoming	0.088	0.090	0.091	0.096	0.100	0.103	0.104	0.102	0.104	0.103	0.096	0.092
United States	0.107	0.109	0.111	0.142	0.145	0.147	0.147	0.148	0.147	0.145	0.115	0.111

8.3.2.2 Future Energy Price Trends

To estimate energy prices in future years, DOE multiplied the 2021 energy prices by the forecast of annual average price changes for each of the nine census divisions from EIA's Reference case in the *Annual Energy Outlook 2022* (AEO 2022). The Reference case is a business-as-usual estimate, given known market, demographic, and technological trends. For each consumer sampled, DOE applied the projection for the census division in which the consumer was located. Figure 8.3.1 shows the projected national electricity price trends for the residential and commercial sectors as a fraction of the 2021 electricity price.

To estimate price trends after 2050, DOE used simple extrapolations of the average annual growth rate in prices from 2046 to 2050 based on the methods used in the 2022 Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP).[22] For more details, see appendix 8E.

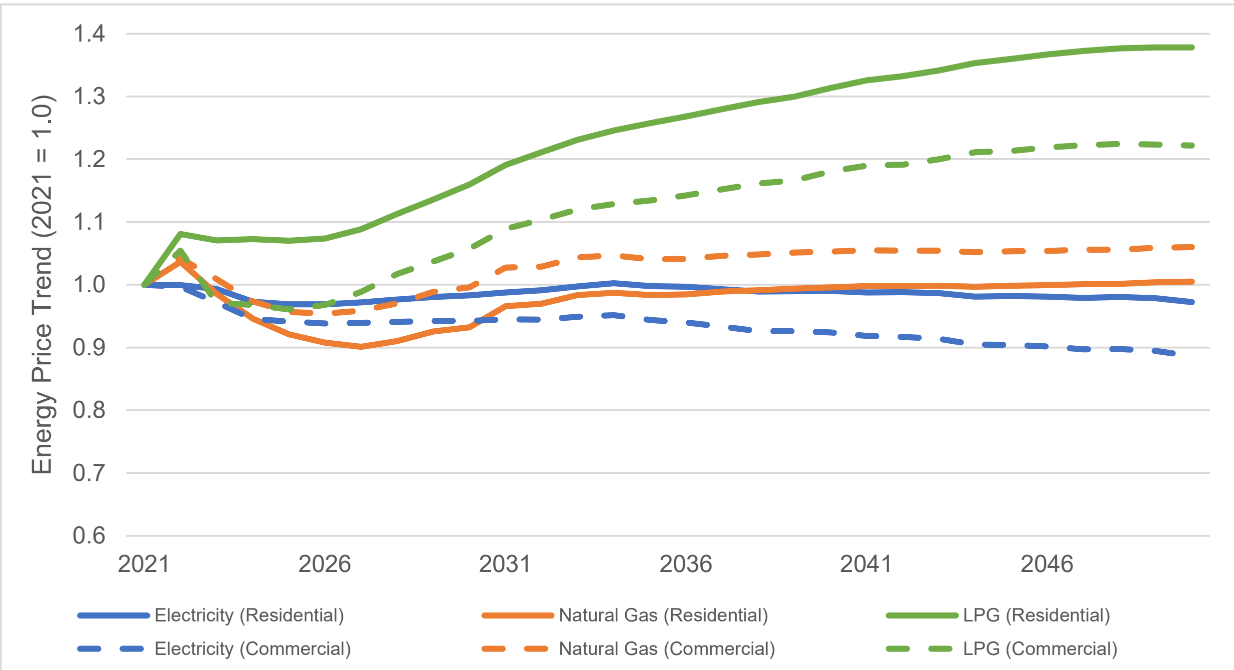

Figure 8.3.1 Projected National Energy Price Factors

8.3.2.3 Summary Energy Price Results for 2028

Table 8.3.3 presents the resulting average and marginal energy prices in 2028. As explained above, the average price is applied to the energy use in the no-new-standards case, while the marginal price is applied to the energy savings when comparing each efficiency level to the no-new-standards case.

Table 8.3.3 Summary of Pool Heaters Average and Marginal Prices in 2028

Energy Price	Residential		Commercial	
	Average	Marginal	Average	Marginal
Electric Pool Heaters				
Electricity (2021$/kWh)	0.128	0.132	0.115	0.130
Gas-fired Pool Heaters				
Electricity (2021$/kWh)	0.159	0.174	0.124	0.153
Natural Gas (2021$/MMBtu)	15.42	9.76	8.40	7.63
LPG (2021$/MMBtu)	22.26	22.26	NA	NA

8.3.3 Repair and Maintenance Costs

The repair cost is the cost to repair the product when a component fails. The maintenance cost is the cost of regular product maintenance. Typically, small incremental increases in product efficiency produce no or only minor changes in repair and maintenance costs compared to baseline efficiency products. The repair and maintenance costs at each considered efficiency level are based on *2021 RSMeans Facilities Maintenance and Repair Data*, manufacturer literature, and consultant input. DOE accounted for regional differences in labor costs using RS Means regional cost factors.

DOE assumed that repair costs would be different at each efficiency level based on the components in the pool heater that had failed (such as the heating element, controls, or condenser fan, or compressor, electronic ignition, and blowers for fan-assisted designs) that would need replacing or repairing. DOE took into account that estimated heat pump pool heaters and higher efficiency gas-fired pool heaters would have higher repair cost due to the presence of more complex components.

DOE assumed that condensing gas-fired pool heaters and heat pump pool heaters would have a higher maintenance cost than non-condensing gas-fired pool heaters and electric resistance pool heaters, respectively, but that this maintenance cost would be the same within each technology type. For example, for heat pump pool heaters, DOE included additional preventative maintenance cost items such as cleaning the air filter and checking the evaporator and refrigeration system. The frequency with which maintenance occurs pool heaters was derived based on consultant input: [20] annually – 60 percent of installations; every 2 years – 20 percent of installations; and every 5 years – 20 percent of installations.

Table 8.3.4 shows the annualized repair and maintenance cost estimates for each pool heater product class and efficiency level. For a detailed discussion of the development of maintenance and repair costs, see appendix 8F.

Table 8.3.4 Annualized Repair and Maintenance Cost for Pool Heaters

Product Class	TE_i *%*	Average Annualized Repair and Maintenance Cost *2021$*	Incremental Cost *2021$*
Electric Pool Heater	99%	88.91	--
	387%	95.67	6.76
	483%	95.67	6.76
	534%	95.67	6.76
	551%	95.67	6.76
	595%	95.67	6.76
Gas-fired Pool Heater	69.7%	109.14	--
	81.3%	108.77	(0.38)
	83.3%	109.45	0.31
	94.7%	120.34	11.20

8.3.4 Lifetime

The product lifetime is the age at which a product is retired from service. Because product lifetime varies, DOE used a lifetime distribution to characterize the probability a product will be retired from service at a given age. DOE took into account published studies and manufacturer input, but because the basis for the estimates in the literature was uncertain, DOE developed a method using shipments and survey data to estimate the distribution of consumer pool heater lifetimes in the field.

DOE assumed that the probability function for the annual survival of consumer pool heaters would take the form of a Weibull distribution. A Weibull distribution is a probability distribution commonly used to measure failure rates.[23] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a specific fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}}, for\ x > \theta, \text{ and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Eq. 8.11

Where:

P(x) = probability that the appliance is still in use at age *x*,

x = age of appliance in years,

ϑ = delay parameter, which allows for a delay before any failures occur,

α = scale parameter, which would be the decay length in an exponential distribution, and

β = shape parameter, which determines the way in which the failure rate changes through time.

When β = 1, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age. DOE estimated a delay parameter of $\theta = 1$ year, based on the typical manufacturer warranty period for pool heaters. DOE derived a Weibull distribution for pool heater lifetime as part of the pool heater shipments model described in chapter 9, primarily using historical shipments data and pool heater stock data from RECS 1987-2020[24] and 2022 Pkdata.[19] DOE assumed that the distribution of lifetimes would account for the impact of the pool water quality on the life of the product, the level of maintenance of a consumer pool heater, and the fraction of consumers winterizing the consumer pool heater.

Table 8.3.5 shows the Weibull distribution parameters for pool heaters and Figure 8.3.2 displays the Weibull probability distribution. DOE assumed that the lifetimes of electric resistance pool heaters, heat pump pool heaters, and gas-fired pool heaters would be the same (average lifetime is 11.2 years). In addition, DOE assumed that the lifetime of all pool heaters would be the same across the different efficiency levels. For a detailed discussion of the development of consumer pool heater lifetimes, see appendix 8G.

Table 8.3.5 Lifetime Parameters for Pool Heaters

Product Class	Weibull Parameters			Statistics	
	Alpha (scale)	Beta (shape)	Location (delay)	Mean	Median
All Pool Heater	11.01	1.5	1.0	11.0	9.6

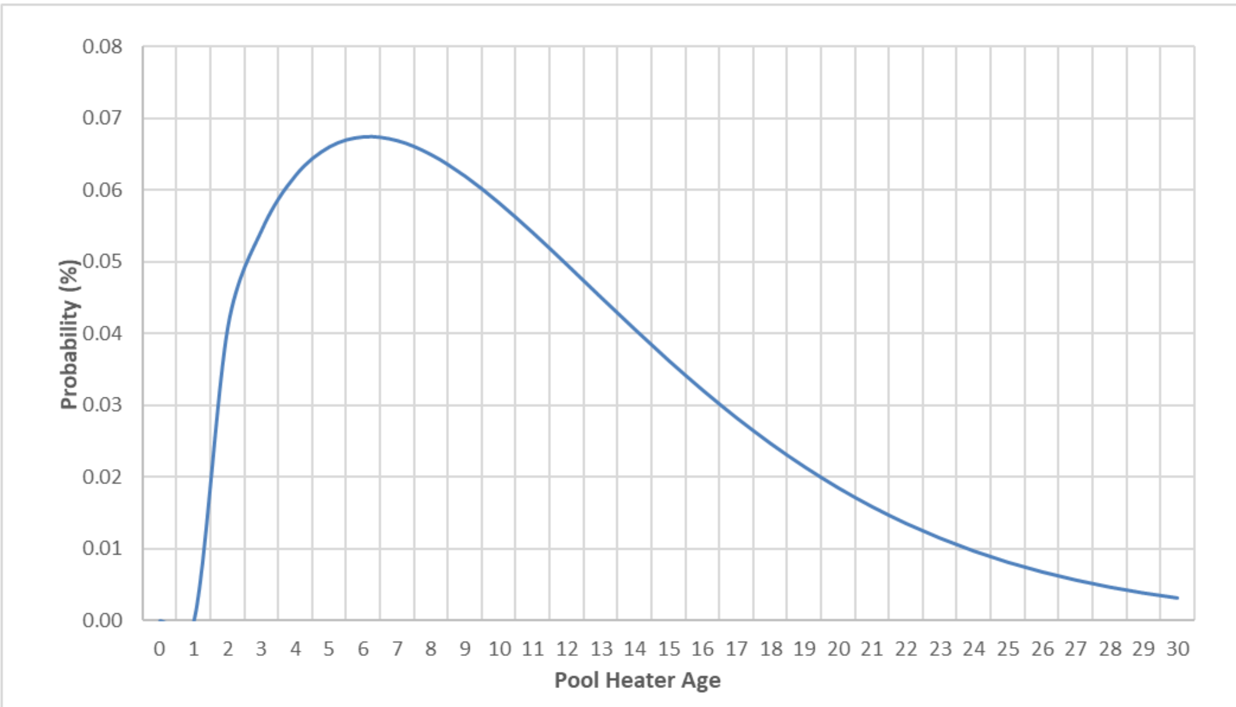

Figure 8.3.2 Weibull Probability Distribution for Pool Heaters

8.3.5 Discount Rates

The discount rate is the rate at which future expenditures and savings are discounted to establish their present value. DOE estimates discount rates separately for residential and commercial end users. For residential end users, DOE calculates discount rates as the weighted average real interest rate across consumer debt and equity holdings. For commercial end users, DOE calculates commercial discount rates as the weighted average cost of capital (WACC), using the Capital Asset Pricing Model (CAPM).

8.3.5.1 Residential

The consumer discount rate is the rate at which future operating costs of residential products are discounted to establish their present value in the LCC analysis. The discount rate value is applied in the LCC to future year energy costs and non-energy operations and maintenance costs in order to calculate the estimated net life-cycle cost of products of various efficiency levels and the life-cycle cost savings of higher-efficiency models as compared to the baseline for a representative sample of consumers.

DOE calculates the consumer discount rate using publicly available data (the Federal Reserve Board's *Survey of Consumer Finance*s (SCF)) to estimate a consumer's required rate of return or opportunity cost of funds related to appliances.[9] In the economics literature, opportunity cost reflects potential foregone benefit resulting from choosing one option over another. Opportunity cost of capital refers to the rate of return that one could earn by investing in an alternate project with similar risk; similarly, opportunity cost may be defined as the cost associated with opportunities that are foregone when resources are not put to their highest-value use.[25]

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. The stream of savings is discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE notes that the LCC does not analyze the appliance purchase decision, so the implicit discount rate is not relevant in this model. The LCC estimates net present value over the lifetime of the product, so the appropriate discount rate will reflect the general opportunity cost of household funds, taking this time scale into account.

Given the long time horizon modeled in the LCC, the application of a marginal interest rate associated with an initial source of funds is inaccurate. Regardless of the method of purchase, consumers are expected to continue to rebalance their debt and asset holdings over the LCC analysis period, based on the restrictions consumers face in their debt payment requirements and the relative size of the interest rates available on debts and assets. DOE estimates the aggregate impact of this rebalancing using the historical distribution of debts and assets. The discount rate is the rate at which future savings and expenditures are discounted to establish their present value.

DOE estimates separate discount rate distributions for six income groups, divided based on income percentile as reported in the SCF. These income groups are listed in Table 8.3.6. This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types, as well as facing different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.3.6 Definition of Income Groups

Income Group	Percentile of Income
1	0 – 19.9
2	20 – 39.9
3	40 – 59.9
4	60 – 79.9
5	80 – 89.9
6	90 - 100

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Shares of Debt and Asset Classes

DOE's approach involved identifying all household debt or equity classes in order to approximate a consumer's opportunity cost of funds over the product's lifetime. This approach assumes that in the long term, consumers are likely to draw from or add to their collection of debt and asset holdings approximately in proportion to their current holdings when future expenditures are required or future savings accumulate. DOE now includes several previously excluded debt types (*i.e.,* vehicle and education loans, mortgages, all forms of home equity loan) in order to better account for all of the options available to consumers.

The average share of total debt plus equity and the associated rate of each asset and debt type are used to calculate a weighted average discount rate for each SCF household (Table 8.3.7). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups.[k]

DOE estimated the average percentage shares of the various types of debt and equity using data from the SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[l] DOE derived the household-weighted mean percentages of each source of across the twenty-one years covered by the eight survey versions. DOE posits that these long-term averages are most appropriate to use in its analysis.

[k] Note that previously DOE performed aggregation of asset and debt types over households by summing the dollar value across all households and then calculating shares. Weighting by dollar value gave disproportionate influence to the asset and debt shares and rates of higher income consumers. DOE has shifted to a household-level weighting to more accurately reflect the average consumer in each income group.
[l] Note that two older versions of the SCF are also available (1989 and 1992); these surveys are not used in this analysis because they do not provide all of the necessary types of data (*e.g.*, credit card interest rates, etc.). DOE feels that the time span covered by the eight surveys included is sufficiently representative of recent debt and equity shares and interest rates.

Table 8.3.7 Average Shares of Household Debt and Asset Types by Income Group (%)

Type of Debt or Equity	Income Group, %						
	1	2	3	4	5	6	All
Debt:							
Mortgage	14.3	22.2	33.1	43.3	47.5	37.0	31.0
Home equity loan	1.5	1.8	2.4	3.5	4.6	7.7	3.1
Credit card	15.8	12.2	9.4	6.1	4.0	1.9	9.3
Other installment loan	31.9	28.0	23.9	16.9	11.5	5.9	21.9
Other line of credit	1.4	1.8	1.5	2.0	2.5	2.3	1.8
Other residential loan	0.7	0.4	0.5	0.4	0.3	0.2	0.5
Equity:							
Savings account	19.1	15.0	11.6	9.0	8.2	7.5	12.5
Money market account	3.5	4.3	3.8	3.6	4.4	6.7	4.1
Certificate of deposit	6.0	6.4	4.6	3.8	3.1	3.3	4.8
Savings bond	1.5	1.6	1.4	1.6	1.4	1.2	1.5
State & Local bonds	0.0	0.1	0.2	0.2	0.4	1.3	0.3
Corporate bonds	0.1	0.1	0.1	0.2	0.1	0.4	0.1
Stocks	2.3	3.2	3.8	4.8	6.0	12.2	4.6
Mutual funds	1.8	3.0	3.7	4.8	6.1	12.5	4.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Rates for Types of Debt

DOE estimated interest rates associated with each type of debt. The source for interest rates for mortgages, loans, credit cards, and lines of credit was the SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019, which associates an interest rate with each type of debt for each household in the survey.

DOE adjusted the nominal rates to real rates for each type of debt by using the annual inflation rate for each year (using the Fisher formula).[m] In calculating effective interest rates for home equity loans and mortgages, DOE also accounted for the fact that interest on both such loans is tax deductible. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation. The specific inflation rates vary by SCF year, while the marginal tax rates vary by SCF year and income bin as shown in Table 8.3.8. For example, a 6 percent nominal mortgage rate has an effective nominal rate of 5.5 percent for a household at the 25 percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

[m] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1. Note that for this analysis DOE used a minimum real effective debt interest rate of 0 percent.

Table 8.3.8 Data Used to Calculate Real Effective Mortgage Rates

Year	Inflation Rate (*%*)	Applicable Marginal Tax Rate by Income Group (*%*)					
		1	2	3	4	5	6
1995	2.81	15.0	15.0	15.0	28.0	28.0	39.6
1998	1.55	15.0	15.0	15.0	28.0	28.0	39.6
2001	2.83	10.0	15.0	15.0	27.5	27.5	39.1
2004	2.68	10.0	15.0	15.0	25.0	25.0	35.0
2007	2.85	10.0	15.0	15.0	25.0	25.0	35.0
2010	1.64	10.0	15.0	15.0	25.0	25.0	35.0
2013	1.46	10.0	15.0	15.0	25.0	25.0	37.3
2016	1.26	10.0	15.0	15.0	25.0	25.0	37.3
2019	1.81	10.0	12.0	12.0	22.0	22.0	36.0

Table 8.3.9 shows the household-weighted average effective real interest rates on debt in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2028.

Table 8.3.9 Average Real Effective Interest Rates for Household Debt (*%*)

Type of Debt	Income Group						
	1	2	3	4	5	6	All
Mortgage	4.09	3.74	3.60	2.92	2.79	2.19	3.18
Home equity loan	4.29	4.34	3.86	3.24	3.11	2.45	3.35
Credit card	9.80	11.02	11.15	11.26	10.90	10.11	10.64
Other installment loan	6.14	7.09	5.98	5.33	4.54	4.42	6.10
Other line of credit	3.73	3.67	6.23	5.47	4.89	5.33	4.97
Other residential loan	6.53	6.41	5.22	4.96	4.33	3.99	5.32

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Rates for Types of Assets

No similar rate data are available from the SCF for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1992-2021). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1992–2021.[26] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1992–2021.[27] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1992–2021.[28,n] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1992-2016 and Bartel Associates for 2017-2021.[34,35,o] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1992–2021.[36] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1992–2021.[37] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[p] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see appendix 8G). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in Table 8.3.10.

Table 8.3.10 Data Used to Calculate Real Effective Capital Gain Rates

Year	Applicable Marginal Tax Rate by Income Group (%)					
	1	2	3	4	5	6
1995	12.5	12.5	12.5	28.0	28.0	33.8
1998	12.5	12.5	12.5	24.0	24.0	29.8
2001	7.5	10.0	15.0	21.3	21.3	27.1
2004	7.5	10.0	15.0	21.3	21.3	27.1
2007	7.5	10.0	15.0	20.0	20.0	25.0
2010	5.0	7.5	15.0	20.0	20.0	25.0
2013	5.0	7.5	15.0	20.0	20.0	27.4
2016	5.0	7.5	15.0	20.0	20.0	27.4
2019	5.0	6.0	6.0	18.5	18.5	26.8

Average real effective interest rates for the classes of household assets are listed in Table 8.3.11. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in the compliance

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[n] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[29,30] From July 2007 to October 2009 the index was known as Wachovia COSI[31] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[32,33]

[o] This index was discontinued in 2016. To calculate the 2017 and after values, DOE used data collected by Bartel Associates.

[p] SCF reports what type of mutual funds the household has (e.g. stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

year. The average nominal interest rates and the distribution of real interest rates by year are shown in appendix 8G.

Table 8.3.11 Average Real Interest Rates for Household Assets (%)

Equity Type	Income Group						
	1	2	3	4	5	6	All
Savings accounts	0.15	0.14	0.14	0.13	0.13	0.12	0.14
Money market accounts	0.30	0.29	0.28	0.25	0.25	0.23	0.27
Certificate of deposit	0.54	0.53	0.51	0.46	0.46	0.42	0.50
Treasury Bills (T-bills)	2.06	2.02	1.94	1.76	1.76	1.62	1.91
State/Local bonds	1.81	1.99	1.90	1.73	1.73	1.59	1.71
AAA Corporate Bonds	2.16	2.18	2.54	2.43	2.34	2.23	2.33
Stocks (S&P 500)	8.77	8.60	8.21	7.45	7.45	6.85	7.70
Mutual funds	7.22	7.29	7.06	6.31	6.39	5.60	6.45

No similar rate data are available from the SCF for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1991-2020). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1991–2020.[26] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1991–2020.[27] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1991–2020.[28,q] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1991–2020.[34,r] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1991–2020.[36,s] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1991–2020.[37] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[t] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see appendix 8H). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in Table 8.3.12.

[q] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[30] From July 2007 to October 2009 the index was known as Wachovia COSI[31] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[32,33]
[r] This index was discontinued in 2016. To calculate the 2017 and after values, DOE compared 1981-2020 data for 30-Year Treasury Constant Maturity Rate and Moody's AAA Corporate Bond Yield to the 20-Bond Municipal Bond Index data.[27,34,36]
[s] From 2003-2005 there are no data. For 2003-2005, DOE used 20-Year Treasury Constant Maturity Rate.[38]
[t] SCF reports what type of mutual funds the household has (e.g. stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8.3.12 Average Capital Gains Marginal Tax Rate by Income Group (%)

Year	Income Group					
	1	2	3	4	5	6
1995	12.5	12.5	12.5	28.0	28.0	33.8
1998	12.5	12.5	12.5	24.0	24.0	29.8
2001	7.5	10.0	15.0	21.3	21.3	27.1
2004	7.5	10.0	15.0	21.3	21.3	27.1
2007	7.5	10.0	15.0	20.0	20.0	25.0
2010	5.0	7.5	15.0	20.0	20.0	25.0
2013	5.0	7.5	15.0	20.0	20.0	27.4
2016	5.0	7.5	15.0	20.0	20.0	27.4
2019	5.0	6.0	6.0	18.5	18.5	26.8

Average real effective interest rates for the classes of household assets are listed in Table 8.3.13. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in the compliance year. The average nominal interest rates and the distribution of real interest rates by year are shown in appendix 8H.

Table 8.3.13 Average Real Interest Rates for Household Assets (%)

Equity Type	Income Group						
	1	2	3	4	5	6	All
Savings accounts	0.24	0.23	0.22	0.20	0.20	0.19	0.22
Money market accounts	0.48	0.47	0.45	0.41	0.41	0.37	0.43
Certificate of deposit	0.76	0.74	0.71	0.64	0.64	0.59	0.71
Treasury Bills (T-bills)	2.25	2.21	2.12	1.93	1.93	1.78	2.08

Equity Type	Income Group						
	1	2	3	4	5	6	All
State/Local bonds	1.86	2.05	1.96	1.78	1.78	1.64	1.77
AAA Corporate Bonds	2.30	2.33	2.71	2.59	2.49	2.38	2.49
Stocks (S&P 500)	8.84	8.67	8.27	7.51	7.51	6.91	7.76
Mutual funds	7.31	7.37	7.13	6.38	6.46	5.67	6.52

Discount Rate Calculation and Summary

Using the asset and debt data discussed above, DOE calculated discount rate distributions for each income group as follows. First, DOE calculated the discount rate for each consumer in each of the versions of the *SCF*, using the following formula:

$$DR_i = \sum_j Share_{i,j} \times Rate_{i,j}$$

Eq. 8.12

Where:

DR_i = discount rate for consumer *i*,

$Share_{i,j}$ = share of asset or debt type *j* for consumer *i*, and

$Rate_{i,j}$ = real interest rate or rate of return of asset or debt type *j* for consumer *i*.

The rate for each debt type is drawn from the *SCF* data for each household. The rate for each asset type is drawn from the distributions described above.

Once the real discount rate was estimated for each consumer, DOE compiled the distribution of discount rates in each survey by income group by calculating the proportion of consumers with discount rates in bins of 1 percent increments, ranging from 0-1 percent at the low end to 30 percent and greater at the high end. Giving equal weight to each survey, DOE compiled the overall distribution of discount rates.

Table 8.3.14 presents the average real effective discount rate and its standard deviation for each of the six income groups. To account for variation among households, DOE sampled a rate for each RECS household from the distributions for the appropriate income group. (RECS provides household income data.) Appendix 8H presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.3.14 Average Real Effective Discount Rates

Income Group	Discount Rate (%)
1	4.71
2	4.95
3	4.51
4	3.80
5	3.44
6	3.19
Overall Average	4.26

Source: Board of Governors of the Federal Reserve System, Survey of Consumer Finances (1995 – 2019)

8.3.5.2 Commercial/Industrial

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. DOE derived the discount rates for the LCC analysis by estimating the cost of capital for companies or public entities that purchase consumer furnaces. For private firms, the weighted average cost of capital (WACC) is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment. Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the firm of equity and debt financing, as estimated from financial data for publicly traded firms in the sectors that purchase consumer furnaces.[39] As discount rates can differ across industries, DOE estimates separate discount rate distributions for a number of aggregate sectors with which elements of the LCC building sample can be associated.

Damodaran Online, the primary source of data for this analysis, is a widely used source of information about debt and equity financing for most types of firms.[40] The nearly 200 detailed industries included in the Damodaran Online data (shown in a table in Appendix 8G) were assigned to the aggregate sectors shown in Table 8.3.15, which also shows the mapping between the aggregate sectors and CBECS Principal Building Activities (PBAs).[u]

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[u] Previously, Damodaran Online provided firm-level data, but now only industry-level data is available, as compiled from individual firm data, for the period of 1998-2020. The data sets note the number of firms included in the industry average for each year.

Damodaran Online data for manufacturing and other similar industries were assigned to the aggregate Industrial sector, while data for farming and agriculture were assigned to the Agriculture sector. Public entities are included in the sectors Federal Government and State/Local Government, but Damodaran data are not used for these sectors.

Table 8.3.15 Mapping of Aggregate Sectors to CBECS Categories

Sector in DOE Analysis	Applied to CBECS PBAs
Education[v]	Education (14)
Food Sales	Food sales (6)
Food Service	Food service (15)
Health Care	Outpatient health care (8); Inpatient health care (16); Nursing (17);
Lodging	Lodging (18)
Mercantile	Enclosed mall (24); Strip shopping mall (23);
Office	Office (2)
Public Assembly	Public assembly (13)
Service	Service (26)
All Commercial	All CBECS PBAs, including those specified above
Industrial	Not in CBECS
Agriculture	Not in CBECS
Federal Government	Not in CBECS
State/Local	Not in CBECS

Note: CBECS only includes buildings used by firms in "commercial" sectors, so Industrial, Agriculture, Federal Government, and State/Local Government have no associated PBA identifier. However, discount rate distributions are required for these sectors because they are significant consumers of some types of appliances and energy-consuming equipment.

For private firms, DOE estimated the cost of equity using the capital asset pricing model (CAPM).[41] CAPM assumes that the cost of equity (k_e) for a particular company is proportional to the systematic risk faced by that company, where high risk is associated with a high cost of equity and low risk is associated with a low cost of equity. In CAPM, the systematic risk facing a firm is determined by several variables: the risk coefficient of the firm (β), the expected return on risk-free assets (R_f), and the equity risk premium (*ERP*). The cost of equity can be estimated at the industry level by averaging across constituent firms. The risk coefficient of the firm indicates the risk associated with that firm relative to the price variability in the stock market. The expected return on risk-free assets is defined by the yield on long-term government bonds. The *ERP* represents the difference between the expected stock market return and the risk-free rate. The cost of equity financing is estimated using the following equation, where the variables are defined as above:

[v] This sector applies to private education, while public education is covered under the later discussion of buildings operated by state and local government entities.

$$k_{ei} = R_f + \beta_i \times ERP$$

Eq. 8.13

Where:

k_{ei} = cost of equity for industry i,

R_f = expected return on risk-free assets,

β_i = risk coefficient of industry i, and

ERP = equity risk premium.

Several parameters of the cost of capital equations can vary substantially over time, and therefore the estimates can vary with the time period over which data is selected and the technical details of the data averaging method. For guidance on the time period for selecting and averaging data for key parameters and the averaging method, DOE used Federal Reserve methodologies for calculating these parameters. In its use of the CAPM, the Federal Reserve uses a forty-year period for calculating discount rate averages, utilizes the gross domestic product price deflator for estimating inflation, and considers the best method for determining the risk free rate as one where "the time horizon of the investor is matched with the term of the risk-free security."[42]

By taking a forty-year geometric average of Federal Reserve data on annual nominal returns for 10-year Treasury bonds, as provided by Damodaran Online, DOE estimated the risk free rates shown in Table 8.3.16.[26,43] DOE also estimated the ERP by calculating the difference between risk free rate and stock market return for the same time period, as estimated using Damodaran Online data on the historical return to stocks.

Table 8.3.16 Risk Free Rate and Equity Risk Premium

Year	Risk-Free Rate (%)	ERP (%)	Year	Risk-Free Rate (%)	ERP (%)
1998	7.15	4.76	2010	7.47	2.51
1999	6.62	5.83	2011	7.80	1.75
2000	6.98	4.52	2012	7.78	2.62
2001	6.98	4.42	2013	7.46	4.59
2002	7.32	2.80	2014	7.65	3.86
2003	7.23	3.16	2015	7.27	3.67
2004	7.33	3.02	2016	7.26	4.21
2005	7.33	3.45	2017	7.36	4.49
2006	7.43	3.16	2018	7.34	3.89
2007	7.61	2.84	2019	7.67	3.55
2008	8.25	1.15	2020	7.75	4.08
2009	7.50	2.46	2021	6.85	5.17

The cost of debt financing (k_d) is the interest rate paid on money borrowed by a company. The cost of debt is estimated by adding a risk adjustment factor (R_a) to the risk-free rate. This risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices. This same calculation can alternatively be performed with industry-level data. Tax rates also impact the cost of debt financing. Using industry average tax rates provided by Damodaran Online, DOE incorporates the after-tax of debt into WACC calculations.

For industry i, the cost of debt financing is:

$$k_{di} = \left(R_f + R_{ai}\right) \times (1 - tx_i)$$

Eq. 8.14

Where:

$k$di = (after-tax) cost of debt financing for industry, *i*,

Rf = expected return on risk-free assets,

Rai = risk adjustment factor to risk-free rate for industry, *i,* and

txi = tax rate of industry, *i*.

DOE estimated the weighted average cost of capital using the following equation:

$$WACC = k_{ei} \times w_{ei} + k_{di} \times w_{di}$$

Eq. 8.15

Where:

$WACC_i$ = weighted average cost of capital for industry *i*,

k_{ei} = cost of equity for industry *i*,

k_{di} = cost of debt financing for industry, *i*,

w_e = proportion of equity financing for industry *i*, and

w_d = proportion of debt financing for industry *i*.

DOE accounts for inflation using the all items Gross Domestic Product deflator.[44] Table 8.3.17 shows the real average WACC values for the major sectors that purchase consumer furnaces. Tables providing full discount rate distributions by sector are included in appendix 8G. While WACC values for any sector may trend higher or lower over substantial periods of time, these values represent a cost of capital that is averaged over major business cycles.

For each entity in the consumer sample for pool heaters, a discount rate is drawn from the distribution calculated for the appropriate sector.

Table 8.3.17 Weighted Average Cost of Capital for Commercial/Industrial Sectors

Sector	Observations	Total Firms	Mean WACC (%)
Education	24	836	7.21%
Food Sales	44	896	5.66%
Food Service	24	1,910	6.51%
Health Care	57	5,720	6.90%
Lodging	24	1,685	6.55%
Mercantile	104	5,718	6.99%
Office	471	47,625	6.89%
Public Assembly	48	3,866	7.27%
Service	161	16,068	6.25%
All Commercial	971	84,482	6.77%
Industrial	1,352	81,480	7.25%
Agriculture	9	306	7.15%
Utilities	107	2,162	4.18%
R.E.I.T/Property	57	4,631	6.62%

Note: "Observations" reflect the number of Damodaran Online detailed industries included in DOE's aggregate sector calculation, while "Total Firms" presents a sum of the number of individual companies represented by those detailed industries. These are two measures of the comprehensiveness of the data used in the WACC calculation.

For publicly owned and operated buildings, the cost of capital can be derived using state and local bond rates and U.S. Treasury bond rates.[34,45] State and local bond rates are used for buildings identified as owned and/or occupied by state or local government entities, such as public schools or local government administrative buildings. Treasury bond rates are used for buildings identified as occupied by federal government entities. Table 8.3.18 presents the average values of discount rates used for public sectors. As for private firms, a discount rate is drawn from the distribution calculated for the appropriate sector.

Table 8.3.18 Discount Rates for Public Sectors that Purchase Pool Heaters

Sector	Observations	Mean Discount Rate (%)
State/Local Government	133 quarters	2.67
Federal Government	399 months	2.06

8.3.6 Compliance Date of Standard

Pursuant to 42 U.S.C. 6295(m), the compliance date of any new energy efficiency standard for pool heaters is 5 years after the final rule is published. Consistent with its published regulatory agenda, DOE assumed that the final rule would be issued by 2023 and that, therefore, the new standards would require compliance beginning in 2028. DOE calculated the LCC and PBP for all consumers as if they each would purchase a new pool heater in 2028.

8.4 ENERGY EFFICIENCY DISTRIBUTIONS

To estimate the percentage of consumers who would be affected by a potential standard at any of the considered efficiency levels, DOE first developed a distribution of efficiencies for products that consumers purchase under the no-new-standards case.

DOE estimated the no-new-standards case efficiency distribution in 2028 for pool heaters based on input during manufacturer interviews regarding the fraction of electric resistance pool heaters, stakeholder comments, and the data about the availability of consumer pool heater models by efficiency using 2022 Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance for heat pump pool heaters,[46] DOE's 2022 Compliance Certification Management System (CCMS) for gas-fired pool heaters,[47] and CEC's 2022 Modernized Appliance Efficiency Database System (MAEDbS) for heat pump and gas-fired pool heaters models,[48] and manufacturer product literature. In addition, DOE assumed that the distribution of no-new-standards case efficiency distribution would vary by region and pool heater market types.[w] For example, certain markets have their own heat pump efficiency requirements or ban the use of pilot lights for gas-fired pool heaters,[x] which limits the availability of certain models. Also, DOE assumed that electric resistance pool heaters would be more common in certain applications compared to heat pump pool heaters (such as in colder climates, indoor installations, or larger spas).

During manufacturer interviews, DOE received input that currently electric resistance pool heaters represent less than 10 percent of total electric pool heater shipments and that gas-fired pool heaters with standing pilot only represented about 4 percent of gas-fired pool heater

[w] For this analysis DOE disaggregated pool heater installations into seven pool heater market types (see chapter 7 for more details: 1) pool heaters in single family homes that serve a swimming pool only; 2) pool heaters in single family homes that serve both a swimming pool and spa; 3) pool heaters in single family homes that serve a spa only; 4) pool heaters in single-family community swimming pools or spas; 5) pool heaters in multi-family community swimming pools or spas; 6) pool heaters in indoor commercial swimming pools or spas; 7) pool heaters in outdoor commercial swimming pools or spas.

[x] The State of Florida code requires heat pump pool heaters to have a minimum COP of at least 4.0 when tested in accordance with low air temperature-mid humidity condition.[49] The State of California code requires that the average COP at the "high air temperature-mid humidity" condition and the COP at the "low air temperature-mid humidity" condition shall be not less than 3.5.[50]

shipments. In addition, DOE accounted for states that currently require higher efficiency heat pump pool heater standards (California,[y] Connecticut,[z] and Florida[aa]) and that have a ban on pilot lights in gas-fired pool heaters (California,[bb] Connecticut,[cc] Florida,[dd] and New York[ee]).

Table 8.4.1 shows the 2028 market share by region and pool heater market type electric pool heaters, which is based on the following assumptions and results in an overall 8.8 percent market share:

(1) For pool type 1, 2, 4, 5, and 7 in the South Atlantic census division (which includes Florida): DOE assumed that there would be smaller market share at efficiency level 1 (EL 1) due to the heat pump efficiency standards in place in Florida and a lower fraction of electric resistance pool heaters (EL 0) than in the rest of the country, since DOE assumed that warmer areas of the country would be better suited for heat pump installations.

(2) For pool type 1, 2, 4, 5, and 7 in the Pacific census division (which includes California): DOE assumed that there would be half the market share at EL 1 and a lower fraction of electric resistance pool heaters than in the rest of the country, but higher than in Florida.

(3) For pool type 1, 2, 4, 5, and 7 in the Rest of the Country: DOE assumed a 6.3 percent market share for electric resistance.

(4) For pool type 3 (single family with spas only): DOE assumed a much larger fraction of electric resistance installations (10 times more compared to pool type 1, 2, 4, 5, and 7).

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[y] California Title 20 Section 1605.3 (g) (3) states: "For heat pump pool heaters manufactured on or after March 1, 2003, the average of the coefficient of performance (COP) at Standard Temperature Rating and the coefficient of performance (COP) at Low Temperature Rating shall be not less than 3.5."[51]

[z] Connecticut's Regulations and Procedures for Establishing Energy Efficiency Standards for Certain Appliances and Products Section 16a-48-4 (S) (4) states: "Heat pump pool heaters shall have a coefficient of performance (COP) of not less than 3.5 at standard temperature rating and at low temperature rating."[52]

[aa] 2017 Florida Energy & Conservation Code Chapter 4 section R403.10.5 states: "Heat pump pool heaters shall have a minimum COP of 4.0 when tested in accordance with AHRI 1160, Table 2, Standard Rating Conditions-Low Air Temperature."[49]

[bb] California Title 20 Section 1605.3 (g) (1) states: "Energy Design Standard for Natural Gas Pool Heaters. Natural gas pool heaters shall not be equipped with constant burning pilots."[51]

[cc] Connecticut's Regulations and Procedures for Establishing Energy Efficiency Standards for Certain Appliances and Products Section 16a-48-4 (S) (2) states: "Natural gas pool heaters shall not be equipped with a constantly burning pilot light." [52]

[dd] 2017 Florida Energy & Conservation Code Chapter 4 section R403.10.4 states: "Natural and LP gas-fired heaters shall not be equipped with constant burning pilots."[49]

[ee] 2020 Energy Conservation Construction Code of New York State Chapter 4 section R404.10.1 states: "Gas-fired heaters shall not be equipped with continuously burning ignition pilots."[53]

(5) For pool type 6 (commercial indoor installations): DOE assumed 73.9 percent market share for electric resistance pool heaters.

Table 8.4.1 Market Share of Electric Resistance Pool Heaters by Consumer Pool Heater Market and Region in 2028

Consumer Pool Heater Market Type* and Region	2028 ERPH Market Share (%)	Sample Weight of Pool Heater Market (%)
Pool Type = 1 and 2, 4, 5, 7 (in South Atlantic)	1.6	53.7
Pool Type = 1 and 2, 4, 5, 7 (in Pacific)	3.2	6.3
Pool Type = 1 and 2, 4, 5, 7 (in Rest of Country)	6.3	29.8
Pool Type = 3 (in South Atlantic)	15.8	0.8
Pool Type = 3 (in Pacific)	31.7	1.1
Pool Type = 3 (in Rest of Country)	63.4	6.8
Pool Type = 6	73.9	1.4
Overall Electric Resistance Market Share	8.8	**100**

* Consumer Pool Heater Market Types are described in chapter 7.

Table 8.4.2 and Table 8.4.3 show the no-new-standards case efficiency distribution in the compliance year for electric pool heaters and gas-fired pool heaters, respectively.

Table 8.4.2 No-New-Standards Case Energy Efficiency Distribution in 2028 for Electric Pool Heaters

Pool Market Type and Region	2028 Market Shae Percentage by Efficiency Level (TE$_I$ in percent)					
	EL 0 (99)	EL 1 (387)	EL 2 (483)	EL 3 (534)	L 4 (551)	EL 5 (595)
Pool Type 1, 2, 4, 5, 7 (South Atlantic)	1.6%	3.8%	69.5%	10.7%	10.7%	3.7%
Pool Type 1, 2, 4, 5, 7 (Pacific)	3.2%	7.1%	65.9%	10.2%	10.2%	3.5%
Pool Type 1, 2, 4, 5, 7 (Rest of Country)	6.3%	22.6%	52.1%	8.1%	8.1%	2.7%
Pool Type 3 (South Atlantic)	15.8%	3.2%	59.4%	9.2%	9.2%	3.1%
Pool Type 3 (Pacific)	31.7%	5.0%	46.5%	7.2%	7.2%	2.4%
Pool Type 3 (Rest of Country)	63.4%	8.9%	20.4%	3.2%	3.2%	1.1%
Pool Type 6	73.9%	3.6%	16.5%	2.6%	2.6%	0.9%

Table 8.4.3 No-New-Standards Case Energy Efficiency Distribution in 2028 for Gas-fired Pool Heaters

Markets	2028 Market Share Percentage by Efficiency Level (TE$_I$ in percent)			
	EL 0 (69.7)	EL 1 (81.3)	EL 2 (83.3)	EL 3 (94.7)
Rest of Country	7%	45%	40%	8%
GPHs with Standing Pilot Not Allowed*	0%	48%	43%	9%

* California, Connecticut, Florida, and New York.

Using the projected distribution of efficiencies for consumer pool heaters, DOE randomly assigned a product efficiency to each household and commercial user drawn from the consumer samples. If a consumer is assigned a product efficiency that is greater than or equal to the efficiency under consideration, the consumer would not be affected by a standard at that efficiency level.

Note that the assignment of consumer pool heater efficiency in the no-new standards case impacts the how the LCC inputs are assigned for baseline efficiency level (EL 0) compared to higher efficiency levels (EL 1-5 for EPHs and EL 1-3 for GPHs). For example, gas-fired pool heaters with standing pilot are banned in certain states and regions, while electric resistance pool heaters are more common in certain applications or regions compared to heat pump pool heaters. This results in the average shipment-weighted energy use of 6,775 kWh/yr for pool heaters with electric resistance pool heaters (compared to the 10,825 kWh/yr reported in Table 7.4.1 in chapter 7 of this TSD).

8.5 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

The LCC calculations were performed for each of the 10,000 consumers in the sample of consumers established for each product class using a Monte Carlo simulation technique. The selection of a consumer in the sample was based on its sample weight (*i.e.*, how representative a particular consumer is of other consumers in the distribution—either regionally or nationally). Each LCC calculation sampled inputs from the probability distributions that DOE developed to characterize the uncertainty and variability in many of the inputs to the analysis. DOE calculated the LCC and PBP for all consumers as if each were to purchase a new pool heater in the expected year of compliance with amended standards.

To calculate the LCC savings and the fraction of consumers impacted, DOE first assigned pool heaters to consumers using the efficiency distribution in the no-new-standards case. For any given efficiency level, DOE measures the change in LCC relative to the LCC in the no-new-standards case, which reflects the estimated efficiency distribution of consumer pool heater in the absence of new or amended energy conservation standards.

For the set of the sample consumers for each product class, DOE also calculated the average installed cost, first year's operating cost, lifetime operating cost, and LCC for each EL. These averages are calculated assuming that all of the sample purchasers purchase a product at each EL. This allows the total installed costs, operating costs, and LCCs for each EL to be compared under the same conditions, across a variety of sample purchasers. DOE used these average values to calculate the PBP for each EL, relative to the baseline EL, in contrast to the LCC savings which are calculated relative to the product it assigned to the consumer in the no-new-standards case. Also note that for this reason, the average LCC savings are often not equal to the difference between the LCC of a specific standard level and the LCC of the baseline product.

The following sections present the key LCC and PBP findings, as well as figures that illustrate the range of LCC and PBP effects among a sample of consumers. A consumer is considered to have received a net LCC cost if the purchaser had negative LCC savings at the EL being analyzed. DOE presents the average LCC savings for affected consumers, which includes only consumers with non-zero LCC savings due to the standard. In other words, the calculation of average LCC savings did not include households with zero LCC savings (no impact from a standard). DOE considered a household to receive no impact at a given efficiency level if in the no-new-standards case DOE assigned it a product having an efficiency equal to or greater than the efficiency level in question. No impacts occur when the no-new-standards case efficiency for a specific consumer equals or exceeds the efficiency at a given EL; a standard would have no effect on the individual consumer because the product installed would already meet the standard.

8.5.1 Summary of Results

Table 8.5.1, Table 8.5.2, Table 8.5.3, and Table 8.5.4 show the LCC and PBP results by EL for electric pool heaters and gas-fired pool heaters. In Table 8.5.1 and Table 8.5.3, the simple payback is measured relative to the baseline product. In Table 8.5.2 and Table 8.5.4, the LCC savings are measured relative to the no-new-standards case efficiency distribution in the compliance year.

Table 8.5.1 Average LCC and PBP Results by Efficiency Level for Electric Pool Heaters

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback *years*	Average Lifetime
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99%	3,673	2,006	16,897	20,570	NA	11
1	387%	4,117	556	4,771	8,888	0.3	11
2	483%	4,226	460	3,968	8,193	0.4	11
3	534%	4,326	420	3,637	7,963	0.4	11
4	551%	4,472	406	3,521	7,993	0.5	11
5	595%	4,666	392	3,404	8,070	0.6	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8.5.2 LCC Savings Relative to the No-New-Standards Case Efficiency Distribution for Electric Pool Heaters

Efficiency Level	TE_i %	Average LCC Savings* ***2021$***	% of Consumers that Experience Net Cost
0	99%	NA	0.0
1	387%	8,090	1.1
2	483%	4,403	2.3
3	534%	1,302	22.4
4	551%	1,130	45.3
5	595%	946	62.9

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 8.5.3 Average LCC and PBP Results by Efficiency Level for Gas-fired Pool Heaters

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback *years*	Average Lifetime
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	69.7%	3,465	1,898	16,230	19,696	NA	11
1	81.3%	3,479	1,819	15,462	18,940	0.2	11
2	83.3%	3,723	1,785	15,182	18,906	2.3	11
3	94.7%	4,655	1,617	13,805	18,460	4.2	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8.5.4 LCC Savings Relative to the No-New-Standards Case Efficiency Distribution for Gas-fired Pool Heaters

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	69.7%	NA	0.0
1	81.3%	783	0.2
2	83.3%	80	39.1
3	94.7%	497	72.6

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

8.5.2 Distribution of Impacts

The figures in this section are presented as frequency charts that show the distribution of LCCs and LCC impacts with their corresponding probability of occurrence. DOE generated the figures for the distributions from a Monte Carlo simulation run based on 10,000 samples.

Efficiency Level Distribution of Total Life-Cycle Cost

Figure 8.5.1 through Figure 8.5.10 show the no-new-standards case LCC distributions for each product class of pool heaters for residential and commercial consumers.

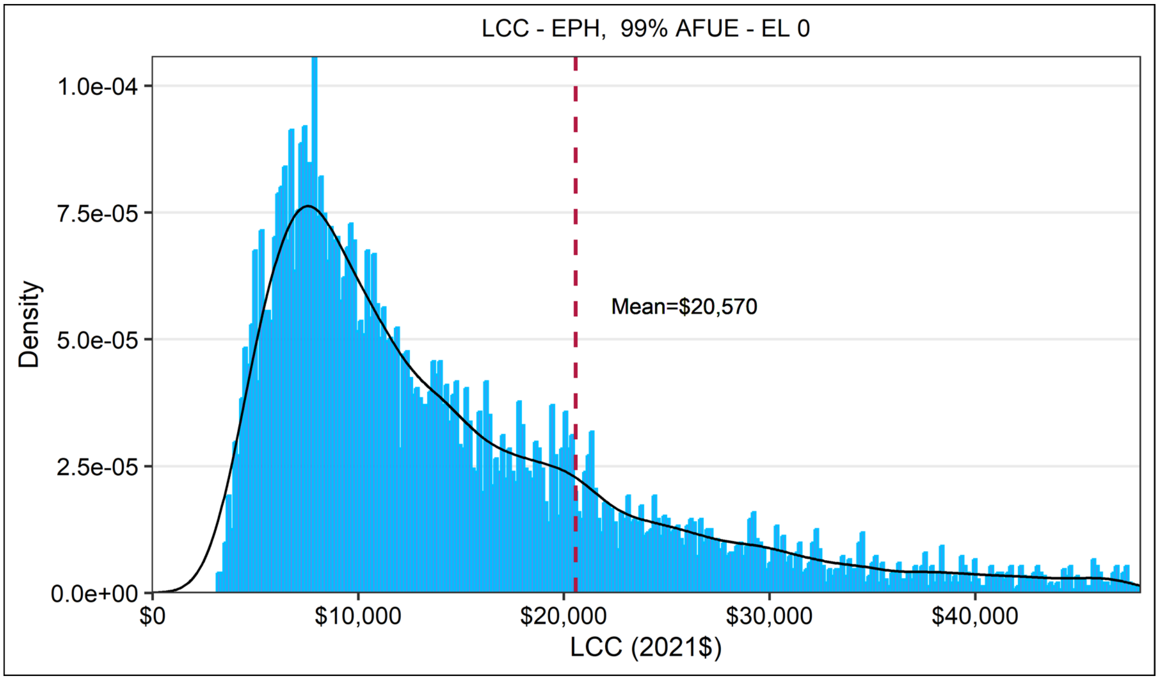

Figure 8.5.1 LCC Distribution: Electric Pool Heaters - EL 0

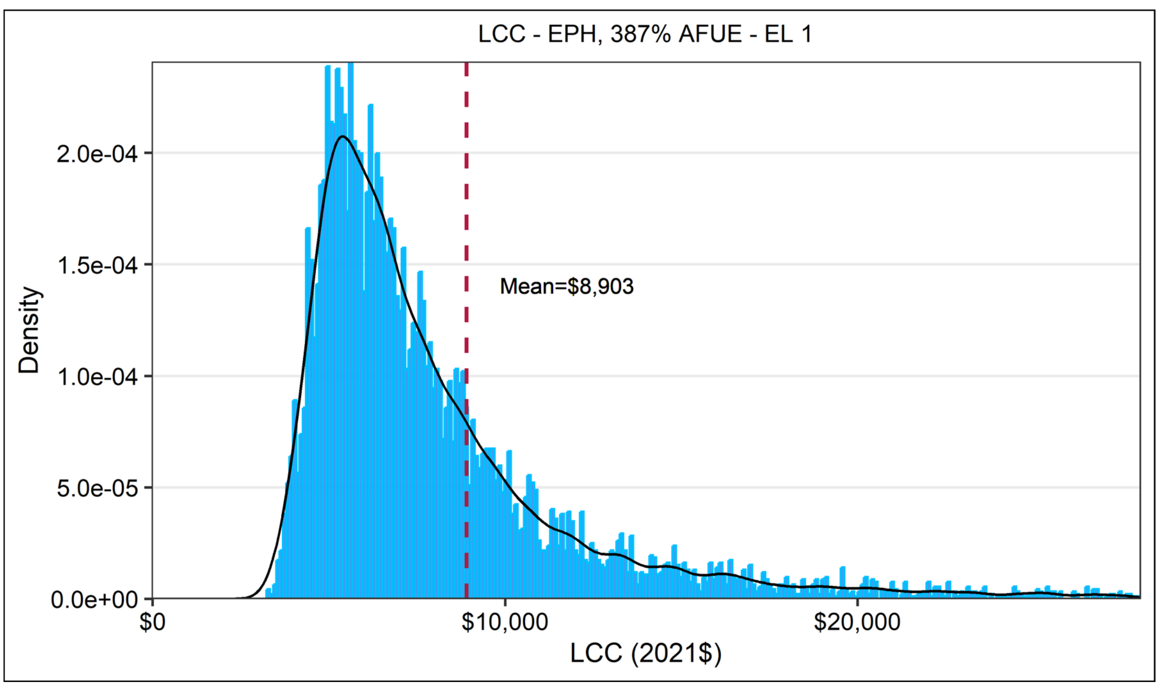

Figure 8.5.2 LCC Distribution: Electric Pool Heaters - EL 1

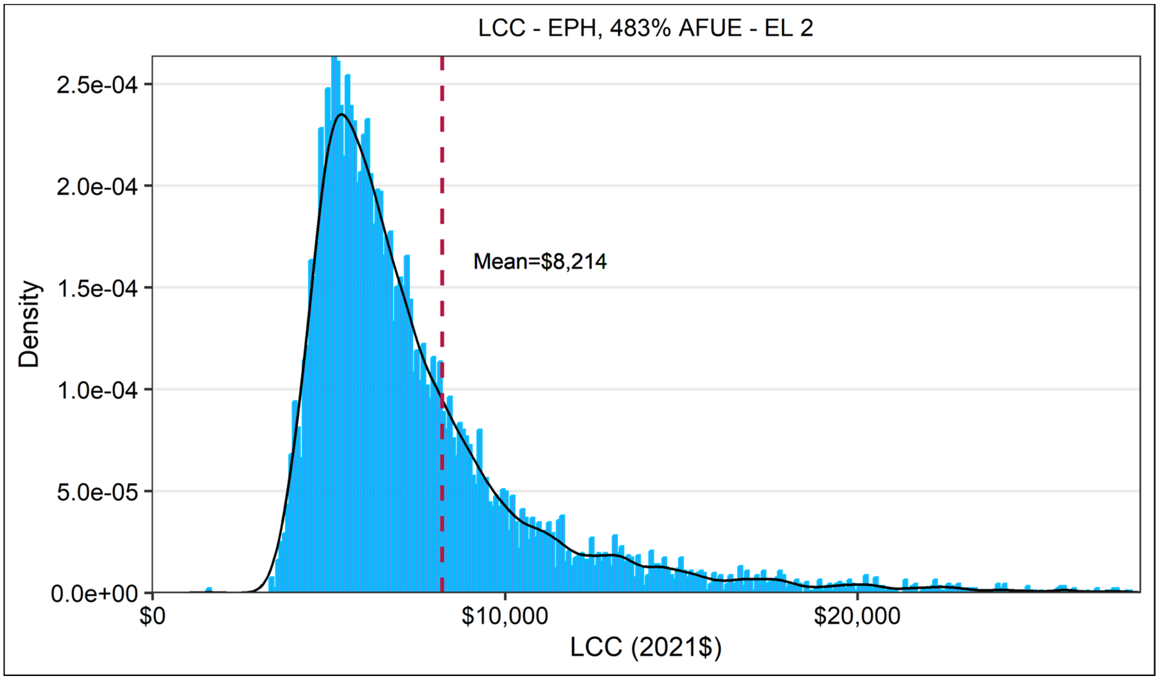

Figure 8.5.3 LCC Distribution: Electric Pool Heaters - EL 2

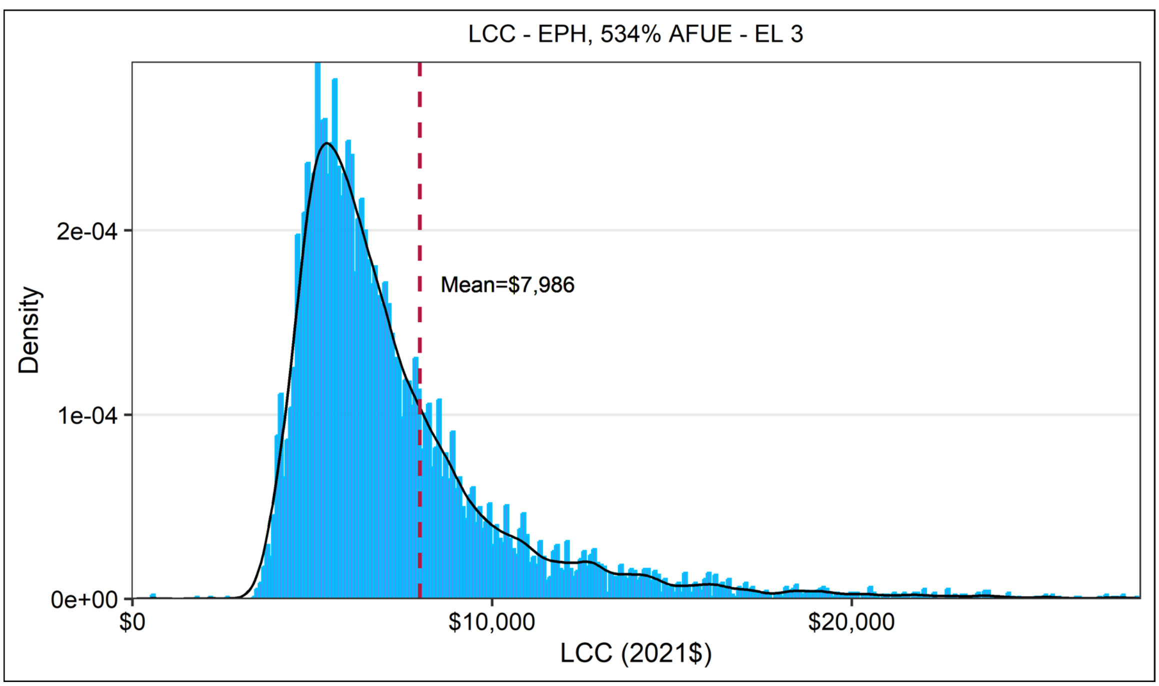

Figure 8.5.4 LCC Distribution: Electric Pool Heaters - EL 3

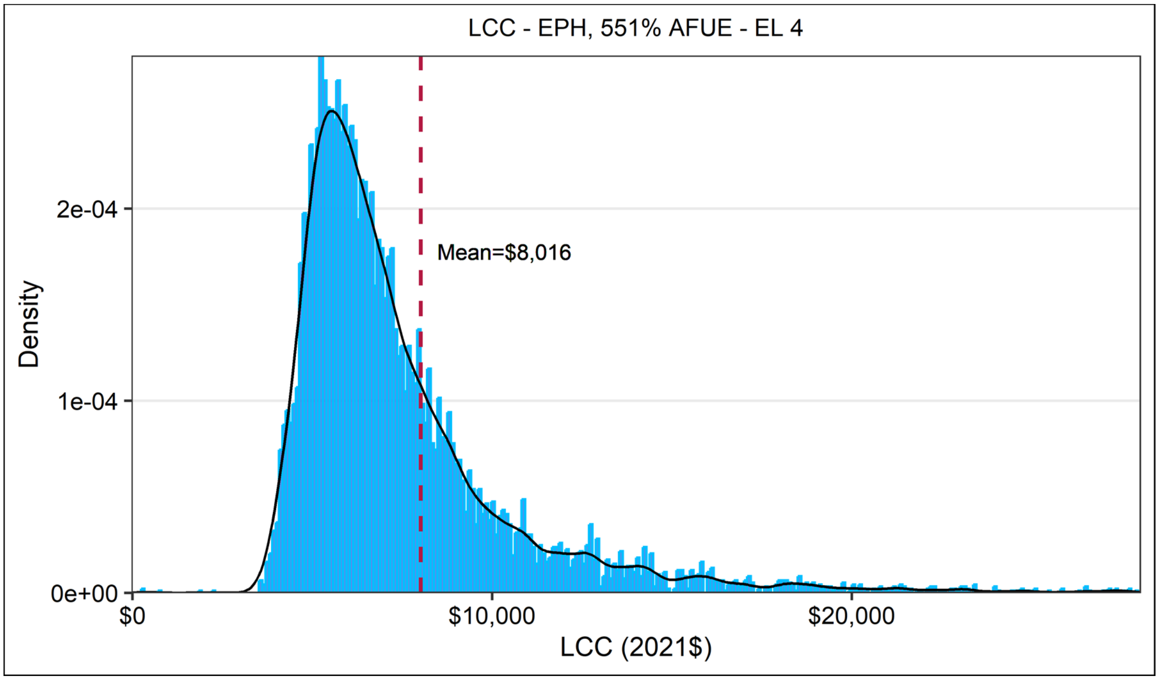

Figure 8.5.5 LCC Distribution: Electric Pool Heaters - EL 4

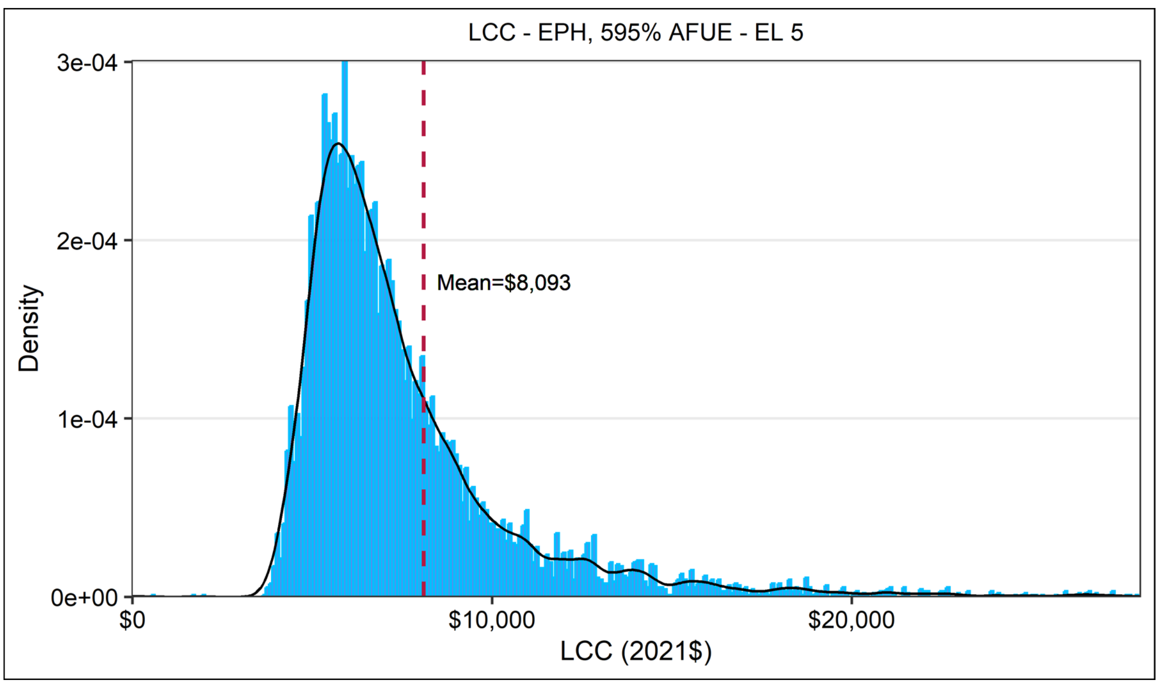

Figure 8.5.6 LCC Distribution: Electric Pool Heaters - EL 5

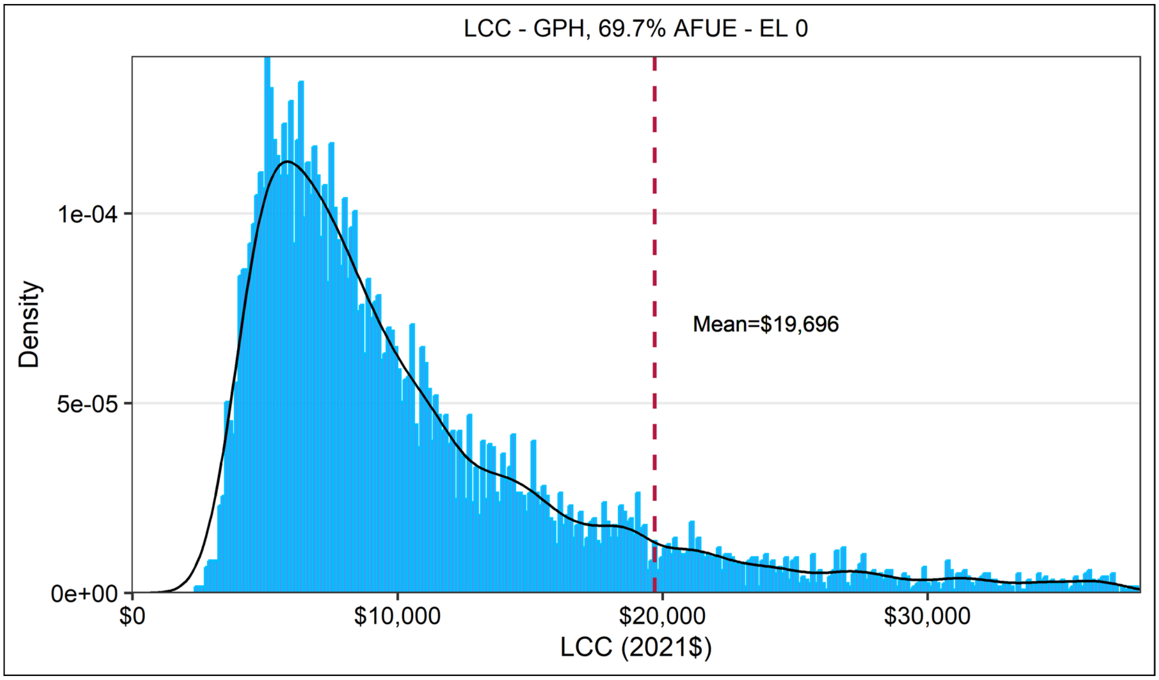

Figure 8.5.7 LCC Distribution: Gas-fired Pool Heaters - EL 0

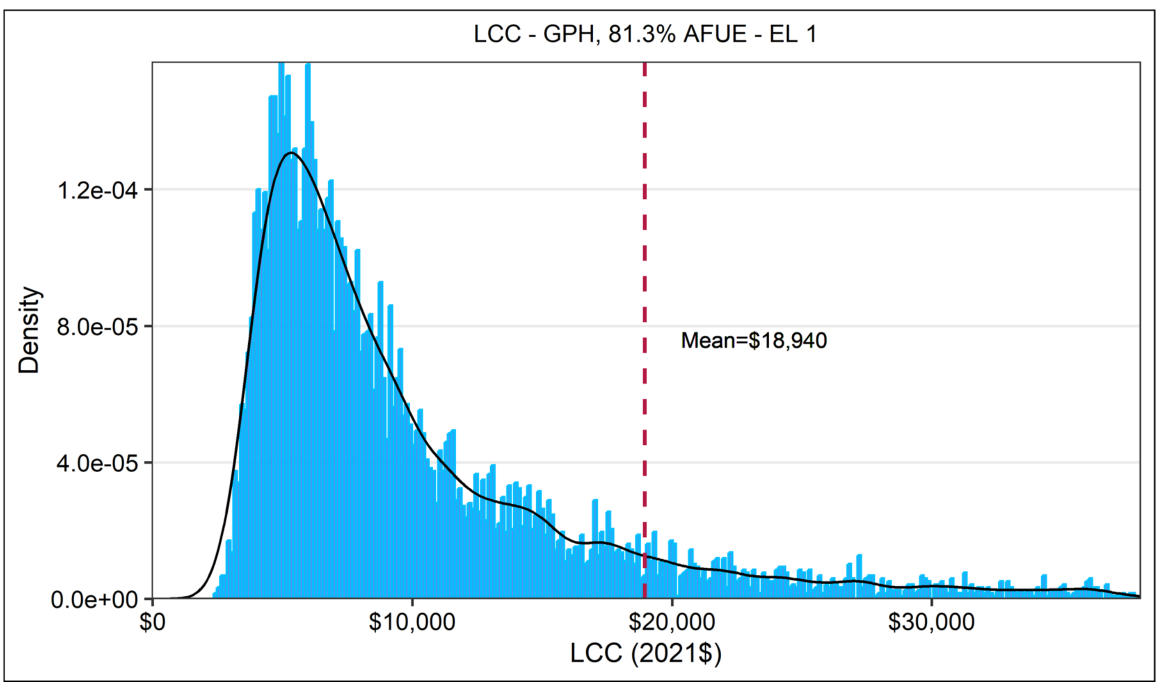

Figure 8.5.8 LCC Distribution: Gas-fired Pool Heaters - EL 1

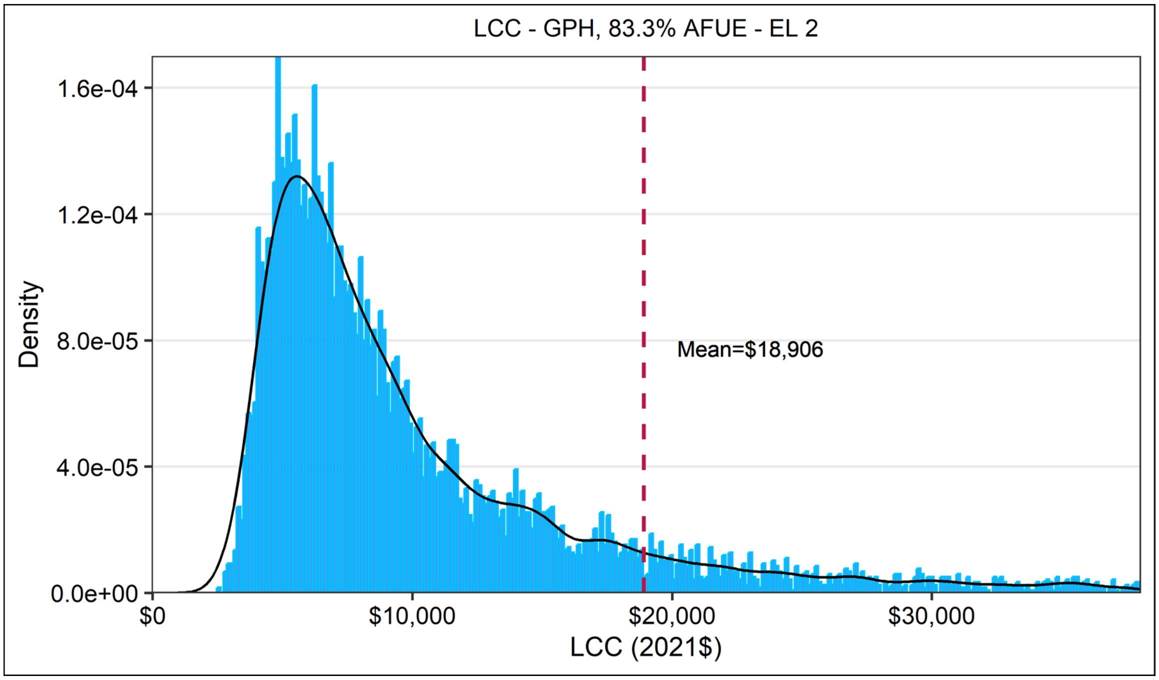

Figure 8.5.9 LCC Distribution: Gas-fired Pool Heaters - EL 2

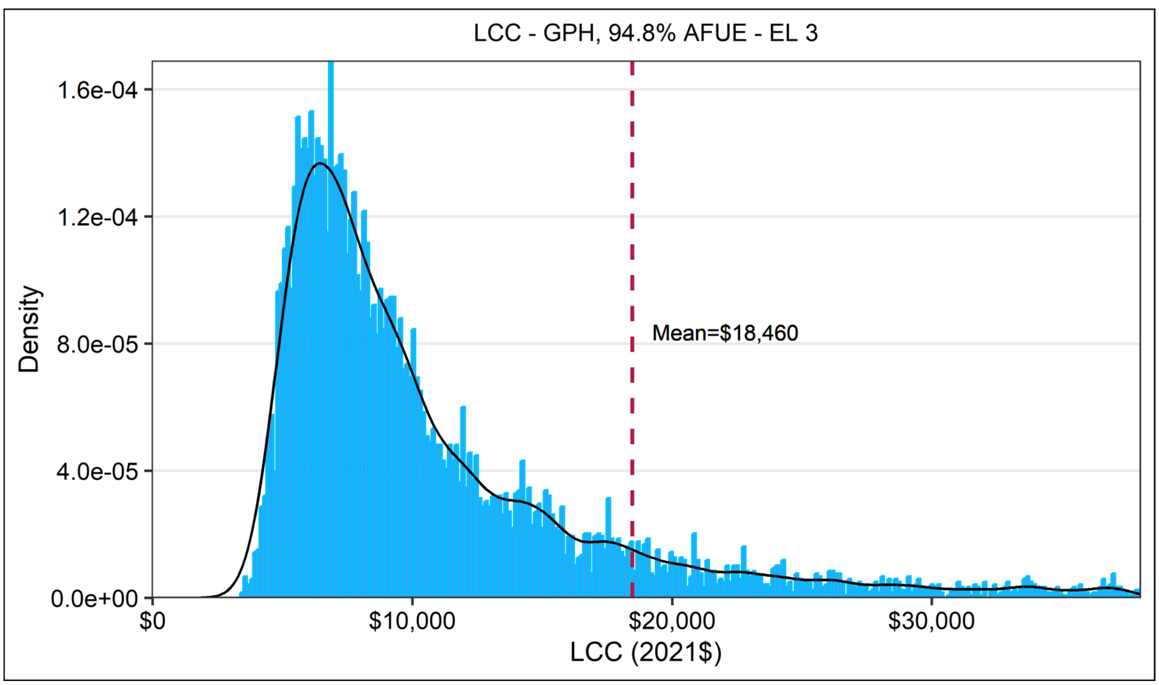

Figure 8.5.10 LCC Distribution: Gas-fired Pool Heaters - EL 3

Efficiency Level Distribution of LCC Savings Impacts

Figure 8.5.11 and Figure 8.5.18 provides the frequency charts that show the distribution of LCC savings for each case efficiency level of electric pool heaters and gas-fired pool heaters.

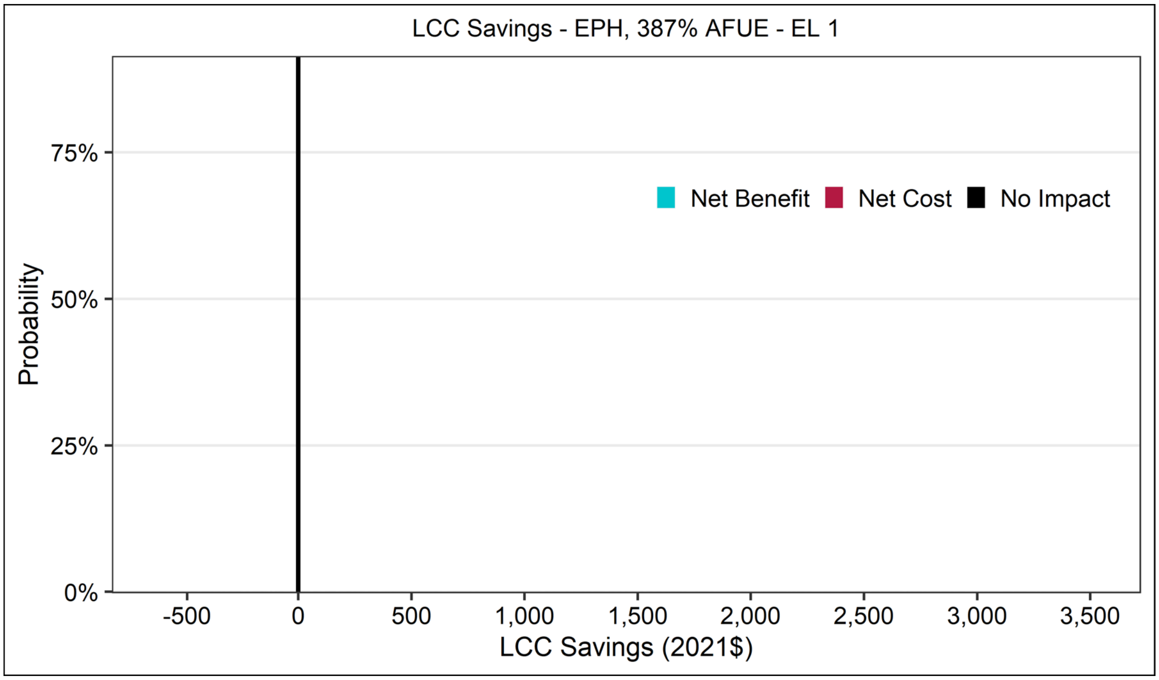

Figure 8.5.11 Distribution of LCC Savings for Electric Pool Heaters for Efficiency Level 1

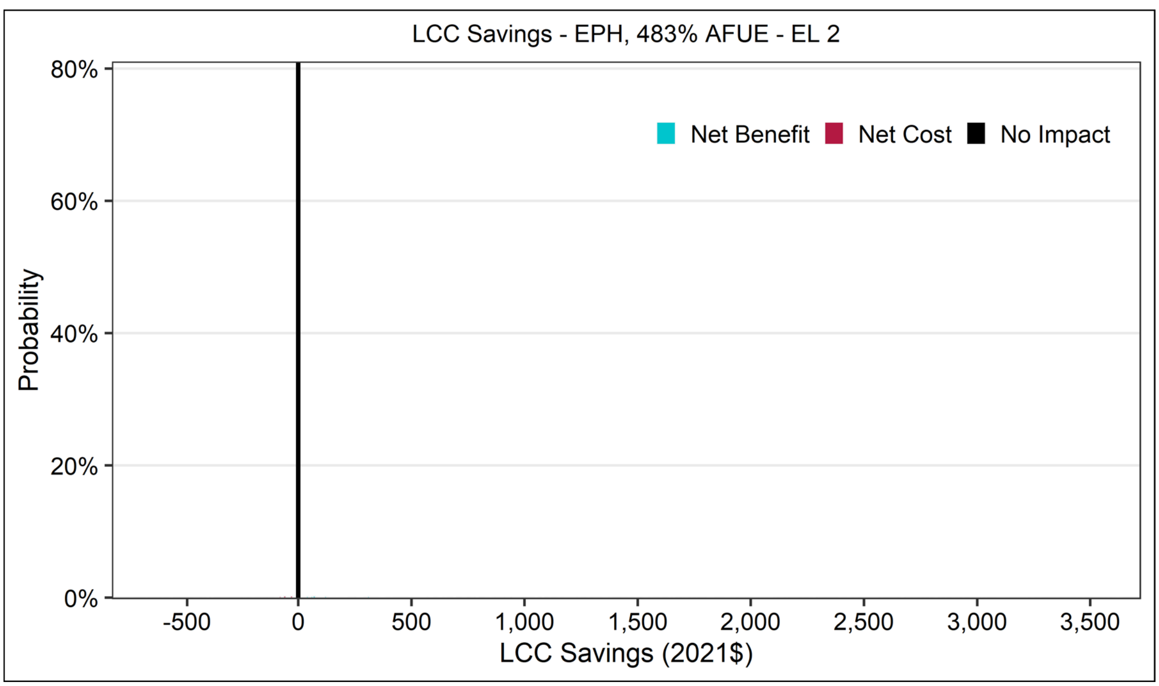

Figure 8.5.12 Distribution of LCC Savings for Electric Pool Heaters for Efficiency Level 2

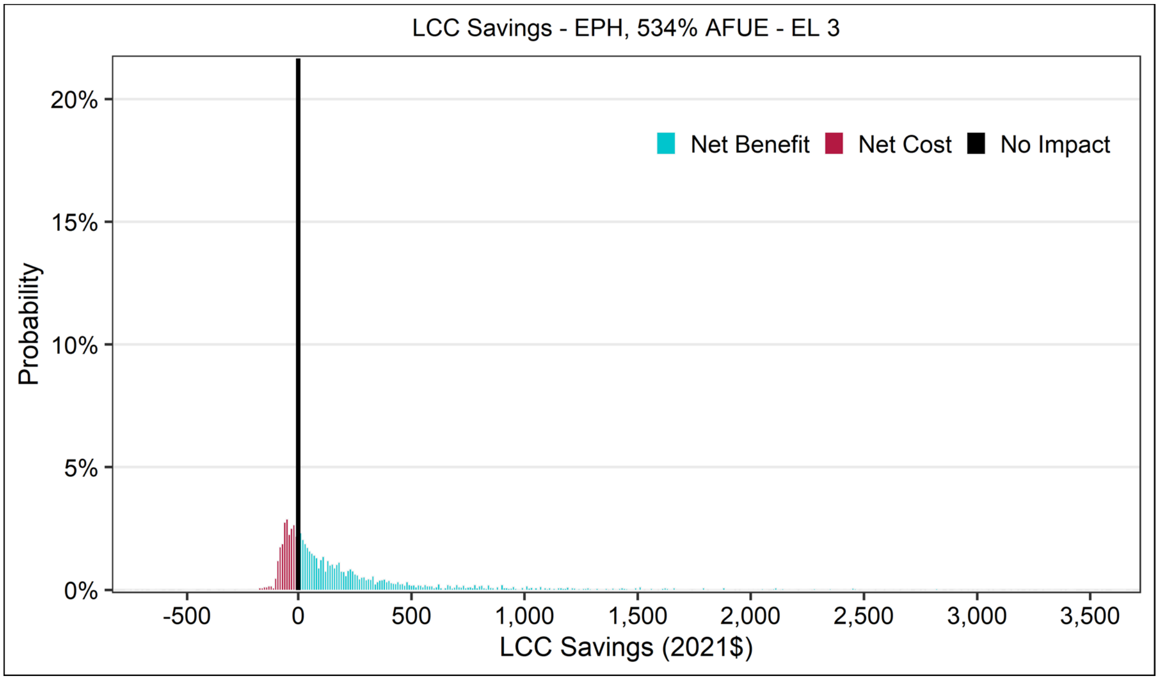

Figure 8.5.13 Distribution of LCC Savings for Electric Pool Heaters for Efficiency Level 3

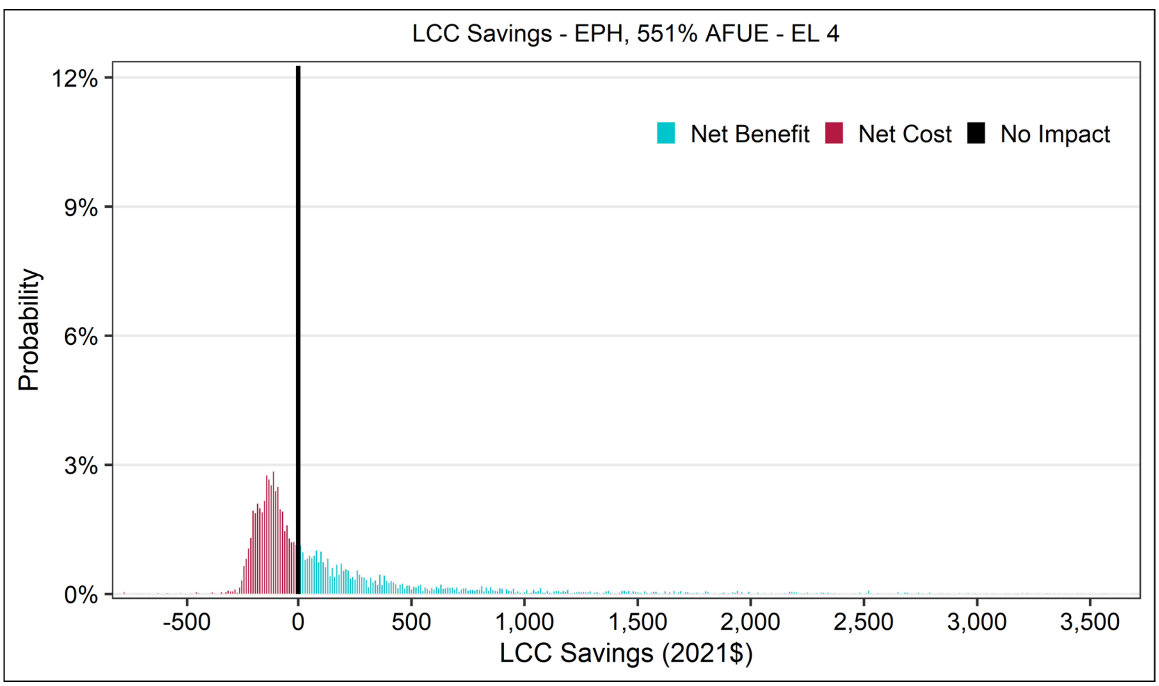

Figure 8.5.14 Distribution of LCC Savings for Electric Pool Heaters for Efficiency Level 4

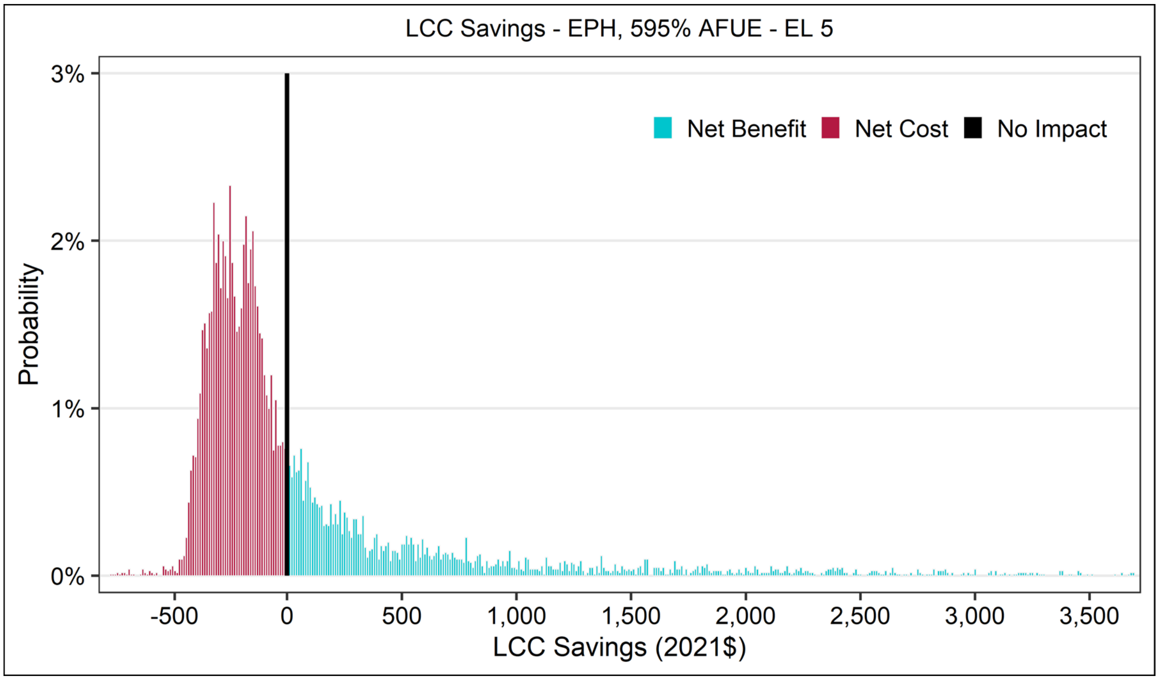

Figure 8.5.15 Distribution of LCC Savings for Electric Pool Heaters for Efficiency Level 5

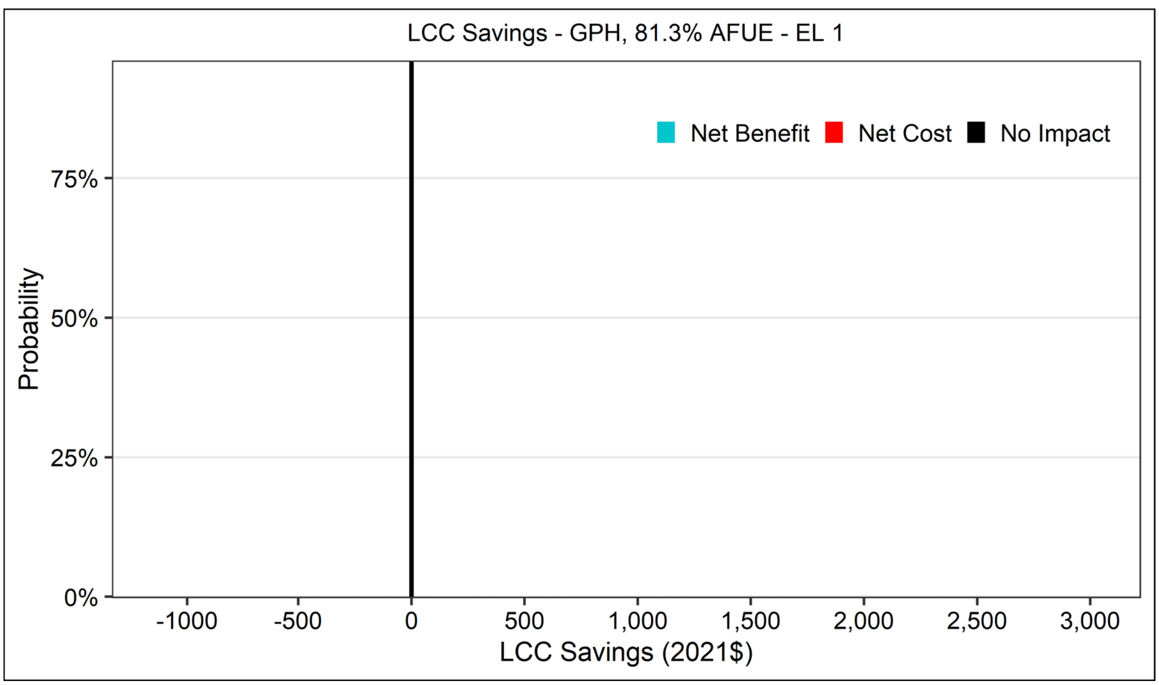

Figure 8.5.16 Distribution of LCC Savings for Gas-fired Pool Heaters for Efficiency Level 1

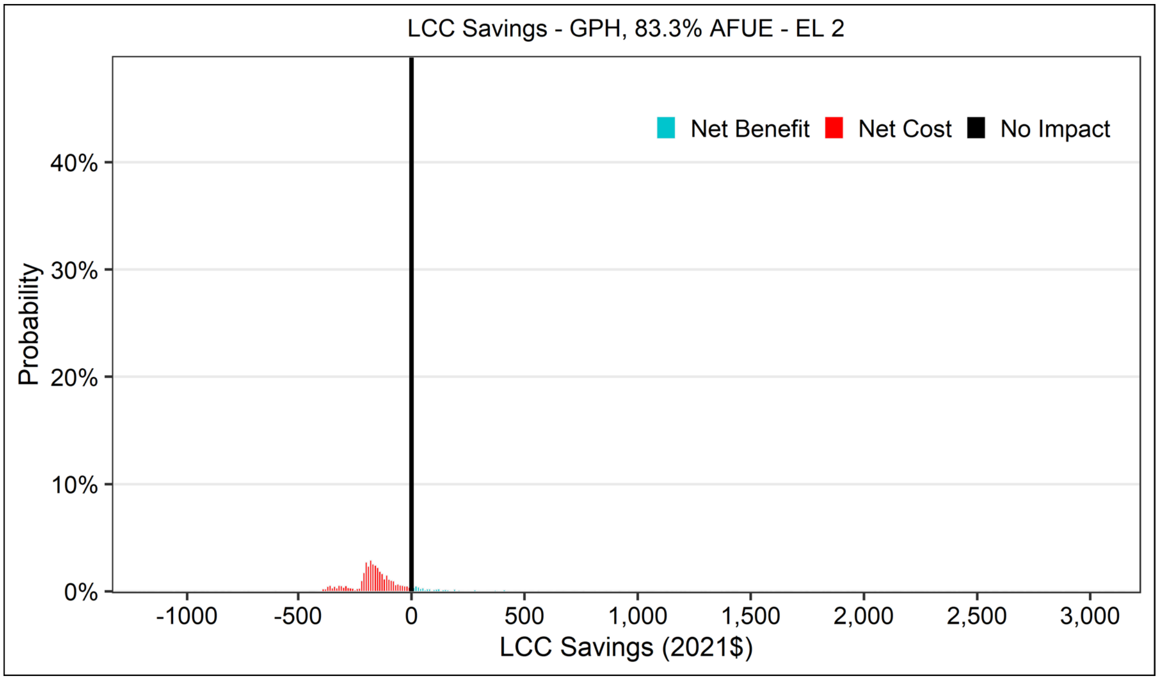

Figure 8.5.17 Distribution of LCC Savings for Gas-fired Pool Heaters for Efficiency Level 2

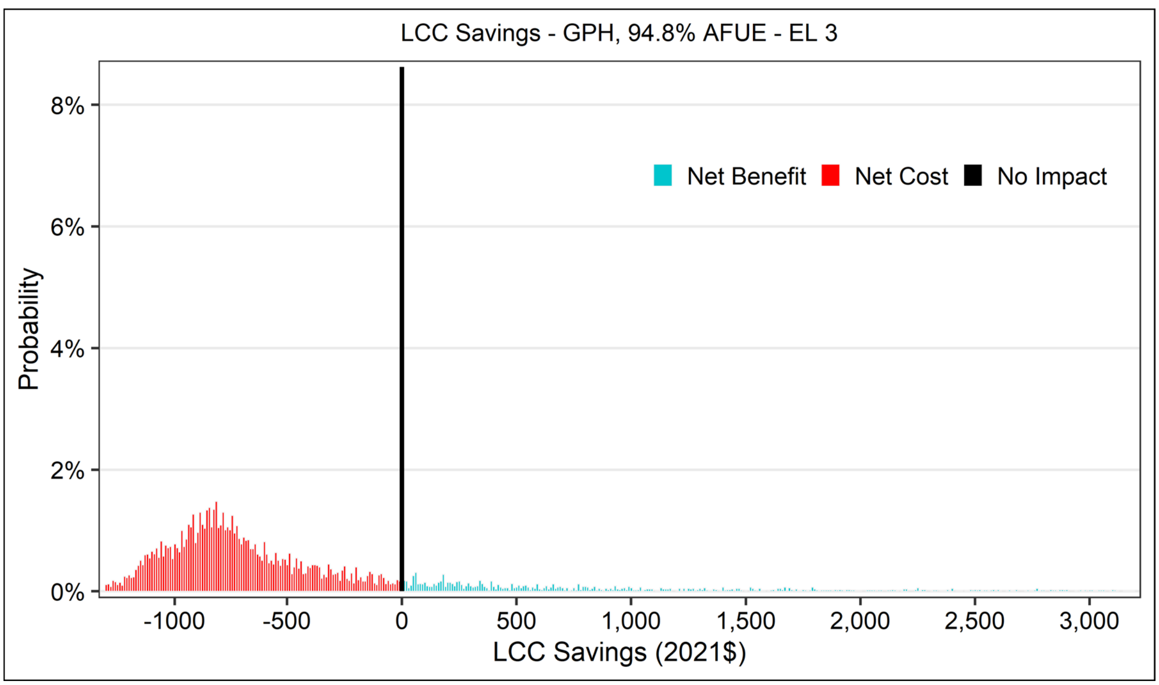

Figure 8.5.18 Distribution of LCC Savings for Gas-fired Pool Heaters for Efficiency Level 3

Range of Life-Cycle Cost Savings by Product Class

Figure 8.5.19 and Figure 8.5.20 show the range of LCC savings for all the efficiency levels considered for electric pool heaters and gas-fired pool heaters as box plots. For each efficiency level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median: 50 percent of the households have lifecycle cost savings above this value. The "whiskers" at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each efficiency level.

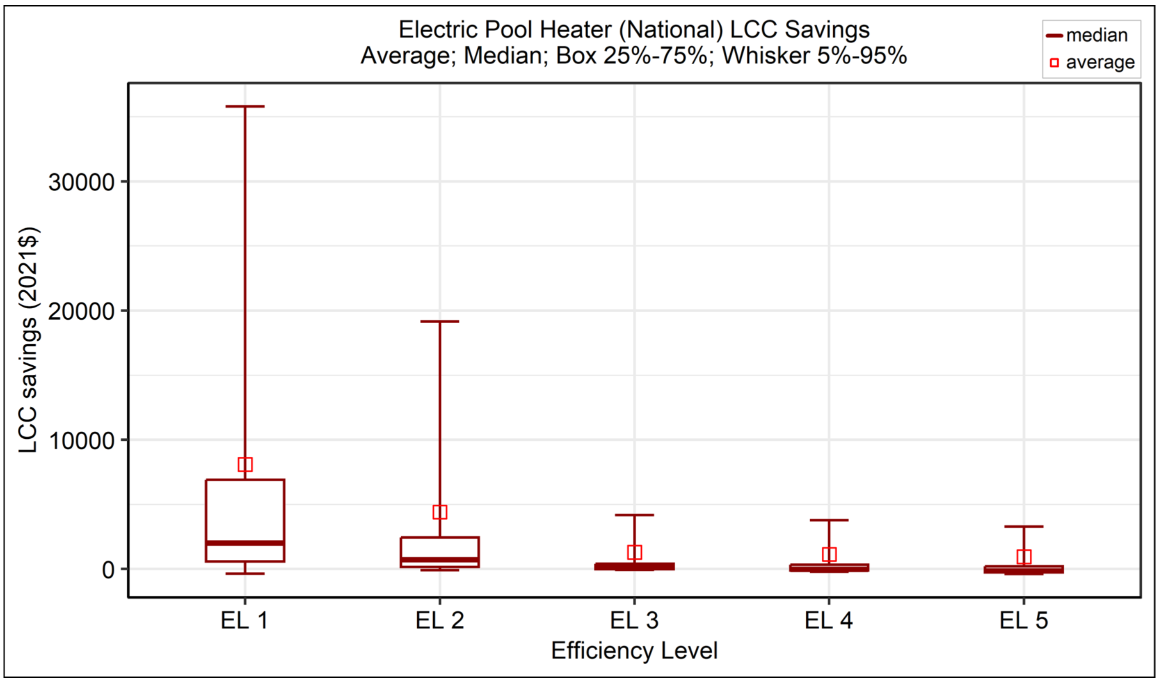

Figure 8.5.19 Distribution of LCC Savings for Electric Pool Heaters

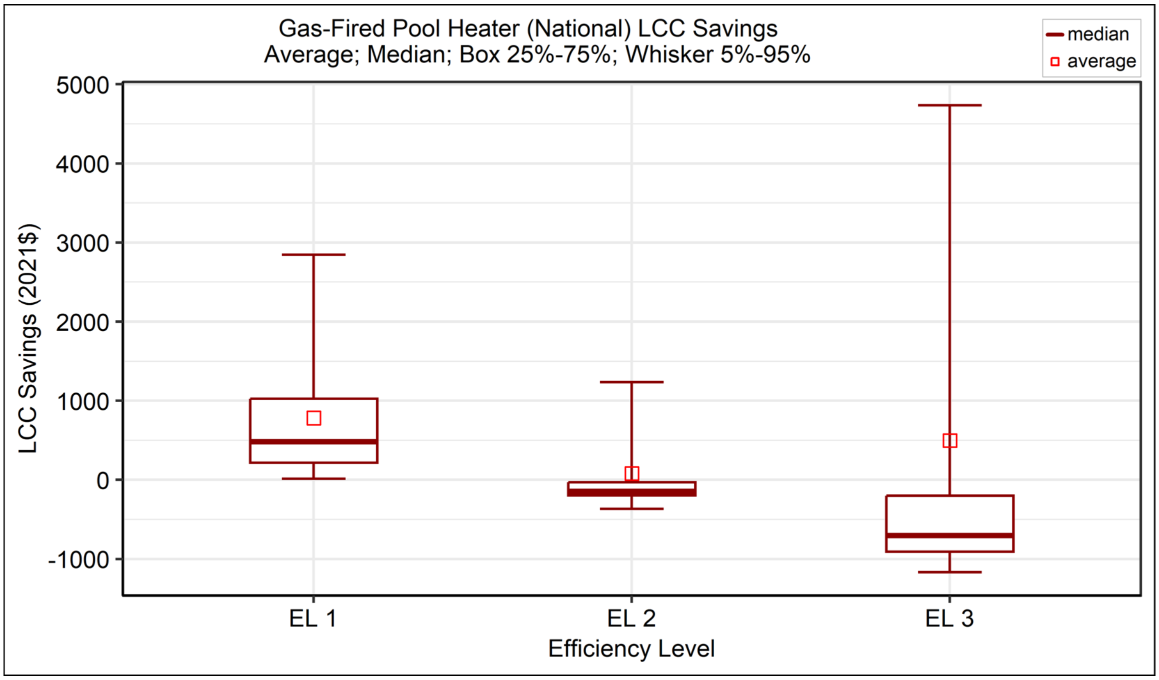

Figure 8.5.20 Distribution of LCC Savings for Gas-fired Pool Heaters

8.5.3 Rebuttable Payback Period

DOE calculates so-called rebuttable PBPs to test the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional product costs attributed to the standard are less than three times the value of the first-year energy cost savings. (42 U.S.C. §6295 (o)(2)(B)(iii))[54]

The basic equation for rebuttable PBP is the same as that used for PBP in section 8.1.1. However, the rebuttable PBP is not based on the use of household samples and probability distributions. Instead, the rebuttable PBP is based on discrete single-point values.

For example, whereas DOE uses a probability distribution of energy prices in the main PBP analysis, it uses only the national average energy price to determine the rebuttable PBP. In addition, the rebuttable PBP relies on the DOE test procedure to determine a product's annual energy consumption. The rebuttable PBP also excludes any maintenance and repair costs.

The following summarizes the single-point average values that DOE used in determining the rebuttable PBP:

- Manufacturing costs, markups, sales taxes, and installation costs are all based on the single-point values used in the distributional LCC and PBP analysis.

- Energy use calculations are based on DOE's pool heater test procedure,[55] which assumes 104 burner operating hours. For gas-fired pool heaters, since the input capacity is fixed (250 kBtu/h) the operating hours are adjusted so that the heating load output is the same between the baseline (EL 0) and higher efficiency options.
- Energy prices are based on national average values for the year that new standards will take effect using AEO 2022.
- An average discount rate or lifetime is not required in the rebuttable PBP calculation.
- The effective date of the standard is assumed to be 2028.

Table 8.5.5 and Table 8.5.6 present the rebuttable payback periods for each product class and considered EL.

Table 8.5.5 Rebuttable Payback Period for Electric Pool Heaters

EL	TE_i	Rebuttable Payback Period *(years)*
1	387	1.36
2	483	1.59
3	534	1.83
4	551	2.22
5	595	2.72

Table 8.5.6 Rebuttable Payback Period for Gas-fired Pool Heaters

EL	TE_i	Rebuttable Payback Period *(years)*
1	81.3	0.12
2	83.3	2.24
3	94.7	7.57

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Estimates of product shipments represent a necessary input for calculations of national energy savings (NES) and net present value (NPV), as well as to the manufacturer impact analysis (MIA). This chapter describes the data and methods the U.S. Department of Energy (DOE) used to project annual product shipments and presents results for consumer pool heater product classes considered in this analysis, specifically electric pool heaters (EPHs) and gas-fired pool heaters (GPHs).

The shipments model divides the shipments of EPHs and GPHs into specific market segments. The model starts from a historical base year and calculates retirements and shipments by market segment for each year of the analysis period. This approach produces an estimate of the total product stock, broken down by age or vintage, in each year of the analysis period. In addition, the product stock efficiency distribution is calculated for the case without new or amended standards ("no-new-standards case") and for each standards case for each product class. The stock distribution is used in the national impact analysis (NIA) to estimate the total costs and benefits associated with each efficiency level.

The shipments model was developed as a Microsoft Excel spreadsheet that is accessible on DOE's Appliance and Equipment Standards Rulemakings and Notices website (www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44). Appendix 10A discusses how to access and utilize the shipments model spreadsheet, which is integrated into the spreadsheet for the NIA. This chapter explains how the shipments model is constructed and provides some summary output.

9.2 SHIPMENTS MODEL METHODOLOGY

The shipments model disaggregates the total stock according to the following characteristics:

1. Product class: Two consumer pool heater product classes were considered in this analysis: EPHs and GPHs.

2. Application market sector: Two market sectors were considered in this analysis: residential sector (single family homes) and commercial sector (such as community pools, schools, private gyms, and lodging).

The consumer pool heater shipments model considers three product market segments (hereafter referred to as "market segments") as follows:

1. *Existing owners of a swimming pool, spa, or hot tub with consumer pool heaters (replacement shipments)*: these are defined as existing swimming pools with consumer

pool heaters installed. This category receives new shipments when existing products are replaced.

2. *New swimming pools, spa, or hot tub with consumer pool heaters (shipments to new swimming pools, spas or hot tubs)*: a certain fraction of new swimming pool, spa, or hot tub owners will install consumer pool heaters in each future year. This fraction is defined as the new swimming pool, spa, or hot tub saturation, which varies by year, market sector, and by product class.

3. *New owners (shipments to new owners)*: these are defined as existing swimming pools, spas, or hot tubs that acquire consumer pool heaters for the first time during the analysis period. The new owners primarily consist of swimming pools, spas, or hot tub owners that previously did not have a consumer pool heater and install a new consumer pool heater. The new owners also include product switching for swimming pools, spas, or hot tub owners that previously had a consumer pool heater and switch to a new consumer pool heater of a different fuel type (electric or gas-fired).

9.2.1 Fundamental Model Equations

The fundamental dependent variable in the shipments model is the product stock, which is represented as a function of analysis year (indexed by *j)*, and product vintage or age (the product age is noted as *a,* and is equal to the analysis year minus the vintage). The stock function is adjusted in each year of the analysis period by new shipments coming in and broken or demolished products being taken out.

For existing stock:

$$Stock_{p,s}(j,a) = Stock_{p,s}(j-1,a-1) - Rem_{p,s}(j,a) + Ship_{p,s}(j-1)$$

Eq. 9.1

For new shipments:

$$Stock_{p,s}(j,a=1) = Ship_{p,s}(j-1)$$

Eq. 9.2

Where:

$Stock_{p,s}(j, a)$ = number of units of product class p, for sector s, and age a in analysis year j,
$Rem_{p,s}(j, a)$ = number of units of product class p, for sector s, and age a removed in analysis year j, and
$Ship_{p,s}(j)$ = number of units product class p and for sector s shipped in year j.

Removals due to product failure contain a survival function $f_{p,s}(a)$ that is used to represent the probability that a unit of product class p for sector s and age a will survive in a given year; equivalently, the probability that this unit will fail is $1-f_{p,s}(a)$.

Total removals in the no-new-standards case are then:

$$Rem_{p,s}(j,a) = \left[1 - f_{p,s}(a)\right] \times Stock_{p,s}(j,a)$$

Eq. 9.3

Shipments are directed to one of the three market segments:

$$Ship_{p,s}(j) = Rpl_{p,s}(j) + NC_{p,s}(j) + NO_{p,s}(j)$$

Eq. 9.4

Where:

$Rpl_{p,s}(j)$ = number of units of product class *p* and for sector *s* replaced in year *j*, which depends on removed units and failed units that are not replaced,
$NC_{p,s}(j)$ = number of new consumer pool heater units of product class *p* and for sector *s* installed in new pools in year *j*, and
$NO_{p,s}(j)$ = number of units of product class *p* and for sector *s* shipped to "new owners" in year *j*.

9.2.2 Replacement Shipments

The shipments model assumes that a certain fraction of units that fails are not replaced, they are deducted from $Rem_{p,s}(j)$ when calculating the required replacements, as represented by the following expression:

$$Rpl_{p,s}(j) = Rem_{p,s}(j) \times (100\% - Frac\_Non\_Rpl_{p,s}(j))$$

Eq. 9.5

Where:

$Frac\_Non\_Rpl_{p,s}(j)$ = faction of units of product class *p* and for sector *s* that fail and are not replaced.

When a consumer pool heater fails, it is removed from the stock. The following retirement function $r_{p,s}(a)$ is used to represent the probability that a unit of product class *p* and for sector *s* will fail at age *a*.

$$Rem_{p,s}(j) = \sum_a r_{p,s}(a) \times Stock_{p,s}(j,a)$$

Eq. 9.6

Retirement functions and product lifetimes are discussed in more detail in chapter 8.

9.2.3 Shipments to New Pools

DOE multiplied new pool units by heated new pool saturation and by consumer pool heater saturations to estimate shipments to the new pool market segment for each consumer pool heater product class. DOE assumed that a certain faction of large spa or hot tub heaters and consumer pool heaters in commercial applications are included in the scope of the analysis. The determination of shipments of product class *p* for new residential pools is represented by the following expression:

$$
\begin{aligned}
NC_p^{(res)}(j) = {} & NP\_res\_in_r(j) \times NP\_Sat\_heated\_res\_in_r(j) \times Sat\_res\_in_p(j) + \\
& NP\_res\_above(j) \times NP\_Sat\_heated\_res\_above(j) \times Sat\_res\_above_p(j) + \\
& NP\_res\_spa(j) \times NP\_Sat\_heated\_res\_spa(j) \times Sat\_res\_spa_p(j)
\end{aligned}
$$

Eq. 9.7

Where:

NP_res_in (*j*) = number of new inground pool units in year *j*,
NP_Sat_heated_res_in (*j*) = heated inground pool saturation for each year *j*,
$Sat\_res\_in_p$ (*j*) = consumer pool heater saturation of product class *p* for inground pools for each year *j*,
NP_res_above (*j*) = number of new aboveground pool units in year *j*,
NP_Sat_heated_res_above (*j*) = heated aboveground pool saturation for each year *j*,
$Sat\_res\_above_p$ (*j*) = consumer pool heaters saturation of product class *p* for aboveground pools for each year *j*,
NP_res_spa (*j*) = number of new hot tub and spa units in year *j*,
NP_Sat_heated_res_spa (*j*) = heated hot tub and spa saturation for each year *j*, and
$Sat\_res\_spa_p$ (*j*) = consumer pool heater saturation of product class *p* for hot tubs and spas for each year *j*.

The determination of shipments of product class *p* for new commercial pools is represented by the following expression:

$$
\begin{aligned}
NC_p^{(com)}(j) = {} & NP\_com(j) \times NP\_Sat\_heated\_com(j) \times Sat\_com_p(j) + \\
& NP\_com\_spa(j) \times NP\_Sat\_heated\_com\_spa(j) \times Sat\_spa_p(j)
\end{aligned}
$$

Eq. 9.8

Where:

NP_com(*j*) = number of commercial pool units in year *j*,
NP_Sat_heated_com(*j*) = heated commercial pool saturation for each year *j*,
Sat_com_p(*j*) = consumer pool heater saturation of product class *p* for commercial pools for each year *j*,
NP_com_spa(*j*) = number of commercial spa units in year *j*,
NP_Sat_heated_com_spa(*j*) = heated commercial spa saturation for each year *j*, and
$Sat\_com\_spa_p$(*j*) = consumer pool heater saturation of product class *p* for commercial spa for each year *j*.

9.2.4 Shipments to New Owners

The third market segment consists of new owners of products and includes an adjustment for switching to a different product class. Because there are no data on the extent of this market segment, DOE estimated historical shipments to this market segment as a residual, using the following equation:

$$NO_{p,s}(j) = Ship_{p,s}(j) - (RU_{p,s}(j) + NU_{p,s}(j))$$

Eq. 9.9

Where:

j = year where historical shipment data is available,
$NO_{p,s}(j)$ = product class p and for sector s new owners (if positive) or adjustment for switching (if negative) for year j,
$Ship_{p,s}(j)$ = historical shipments of product class p and for sector s in year j,
$RU_{p,s}(j)$ = estimated replacement units of product class p and for sector s in year j, and
$NU_{p,s}(j)$ = new units of product class p and for sector s for new homes in year j.

9.3 HISTORICAL DATA INPUTS AND SUPPORTING CALCULATIONS

9.3.1 Historical Shipments for Electric and Gas-fired Pool Heaters

Historical shipments are required (together with retirement function) to calculate replacement shipments and are also used to calibrate DOE's shipments model. For consumer pool heaters, there are limited historical shipments data. Based on the 1993 Technical Support Document (TSD) for pool heaters[1], DOE obtained 1981 and 1990 shipments data for gas-fired pool heater (114,000 for 1981 and 134,000 for 1990). In the April 2010 final rule, Association of Pool & Spa Professionals (APSA) provided DOE with shipment information in the form of a written comment.[2] The shipment data provided was for gas-fired pool heaters from 2003 to 2009 in 2 shipment classifications (<130,000 Btu/h and >130,000 Btu to ≤400,000 Btu/h) and is shown in Table 9.3.1. The shipments classifications are intended to separate between "above ground pools" and "in-ground pools" shipments. The shipment data provided by APSA in 2010 did not specify shipments for electric pool heaters. Finally, DOE also obtained shipments estimates from 2016 Pkdata[3] to calibrate the shipments model. The 2015 Pkdata data provided 2010-2015 estimated total electric and gas-fired pool heater shipments for new residential swimming pools and spas and 2010-2014 estimated total electric and gas-fired pool heater shipments for commercial swimming pools and spas. The 2022 Pkdata provided additional shipments of residential pool heaters from 2003 to 2021 for residential inground pool heater types.[4]

Table 9.3.1 Gas-fired Pool Heater Shipments Provided by APSP during the April 2010 Final Rule

Year*	≤130,000 Btu/h	>130,000-≤400,000 Btu/h	Total
2003	15,000	153,000	168,000
2004	16,000	177,000	193,000
2005	17,000	215,000	232,000
2006	17,000	198,000	215,000
2007	14,000	171,000	185,000
2008	13,000	148,000	161,000
2009	11,000	107,000	118,000

* Note that the shipment year is representative of shipments made from October 1 – September 30 (e.g. 2009 represents shipments from 10/1/2008 – 9/30/2009).

Due to the lack of historical shipments data for both electric and gas-fired pool heaters, DOE "backcasted" the shipments model (i.e., applied the shipments model to years prior to 2021) to estimate historical shipments for consumer pool heaters (see section 9.2 for a full description of the shipments model). DOE used historical data and DOE assumptions, described in the next sections, required in the shipments models to calculate historical pool heater shipments by market segments as follows:

- *New swimming pool and spa market* by using historical new swimming pool and spa installation data (see section 9.3.2), and historical fraction of swimming pools and spas with pool heaters (see section 9.3.3).
- *Replacement market* by using product survival function (see section 9.3.7), historical shipments estimated using the model, and estimated fraction of non-replacements (see section 9.3.6),
- *New owner market* by using historical swimming pool installed stock without a pool heater and estimated fraction of new owners (see section 9.3.5).

DOE then calibrated the historical consumer pool heater shipments models by comparing the total stock of pool heaters reported from historical data sources (see section 9.3.4) to DOE's stock estimates and by comparing the historical data shown above to DOE's estimated historical shipments by varying various parameters (including lifetime Weibull distribution function parameters, fraction of new owners, and fraction of non-replacements).

Figure 9.3.1 shows DOE's modeled historical shipments for electric and gas-fired pool heaters from 1980-2021.

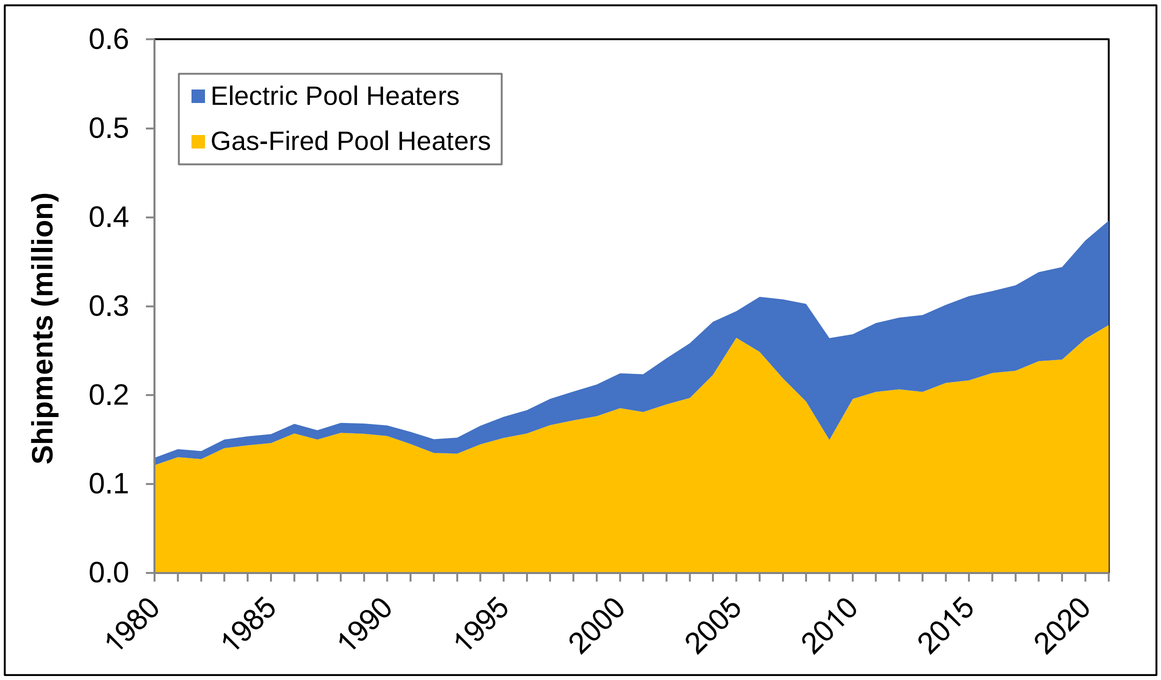

Figure 9.3.1 Estimated Historical Shipments for Electric and Gas-fired Pool Heaters (1980-2021)

9.3.2 Historical New Swimming Pool and Spa data

Historical new swimming pool, hot tub, and spa data (together with saturation fractions) were used to estimate new consumer pool heater shipments. DOE gathered the estimated historical annual number of new residential inground pool constructions and of new residential aboveground pool sales from 1970-2021, estimated historical new residential spa and hot tub sales from 1980-2021, and estimated historical new commercial swimming pools constructions from 2003 to 2021 based on 2022 Pkdata.[4] Figure 9.3.2 shows historical residential inground pool constructions, Figure 9.3.3 shows historical residential aboveground pool sales, Figure 9.3.4 shows historical new residential spas and hot tubs, and Figure 9.3.5 shows historical new commercial swimming pools.[a]

As shown in Figure 9.3.2, residential inground pool constructions overall increased from 1970 to 2005 and reached a historical peak in 2005. After 2005, the residential inground pool constructions experienced a steep decrease from 2006 to 2009 and dropped to near historical low since early 1970s. The residential inground pool constructions stagnated during the period of 2009–2013 and began to recover after 2013. As shown in Figure 9.3.3, residential aboveground pool sales overall increased from 1970 to 2006 (surpassing inground pools in the early 1990s) and reached a historical peak in 2006. After 2006, the residential aboveground pool sales experienced a steep decrease from 2007 to 2009. The residential aboveground pool sales began to recover rapidly after 2009. As shown in Figure 9.3.4, new residential spas and hot tubs overall

[a] Note that DOE did not have any data regarding new commercial spas installations, so DOE assumed that commercial spas installations are equivalent to 50 percent of new commercial swimming pool installations.

increased from 1980 to 2006 and reached a historical peak in 2004. After 2004, the new residential saps and hot tubs experienced a significant decrease from 2005 to 2009. The new residential spas and hot tubs began to recover after 2009. As shown in Figure 9.3.5, new commercial pools overall declined during the period of 2004–2009. The new commercial pools began to recover after 2009.

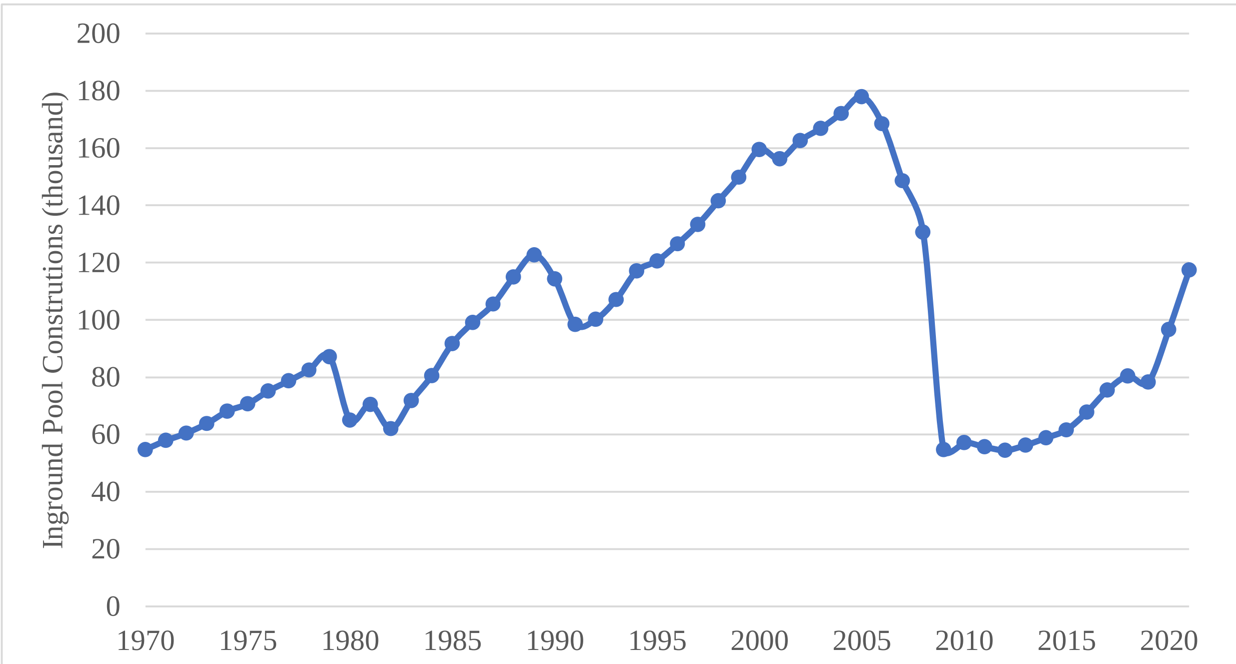

Figure 9.3.2 Estimated Historical Residential Inground Pool Constructions, 1970–2021

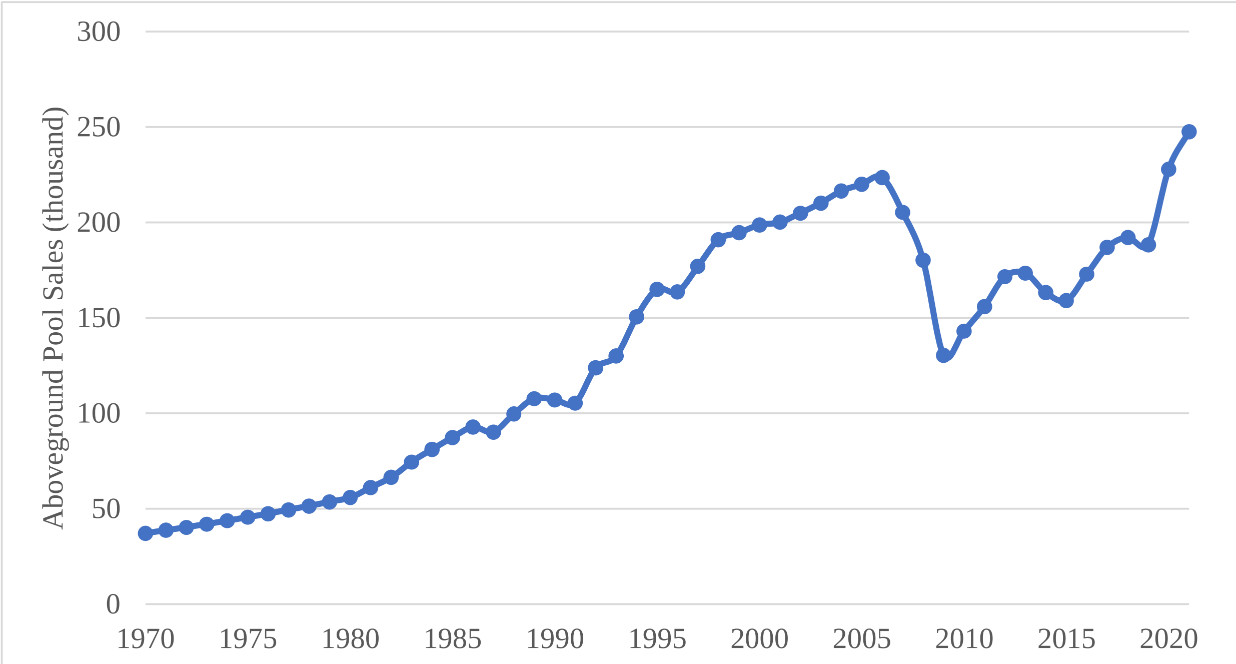

Figure 9.3.3 **Estimated Historical Residential Aboveground Pool Sales,1970–2021**

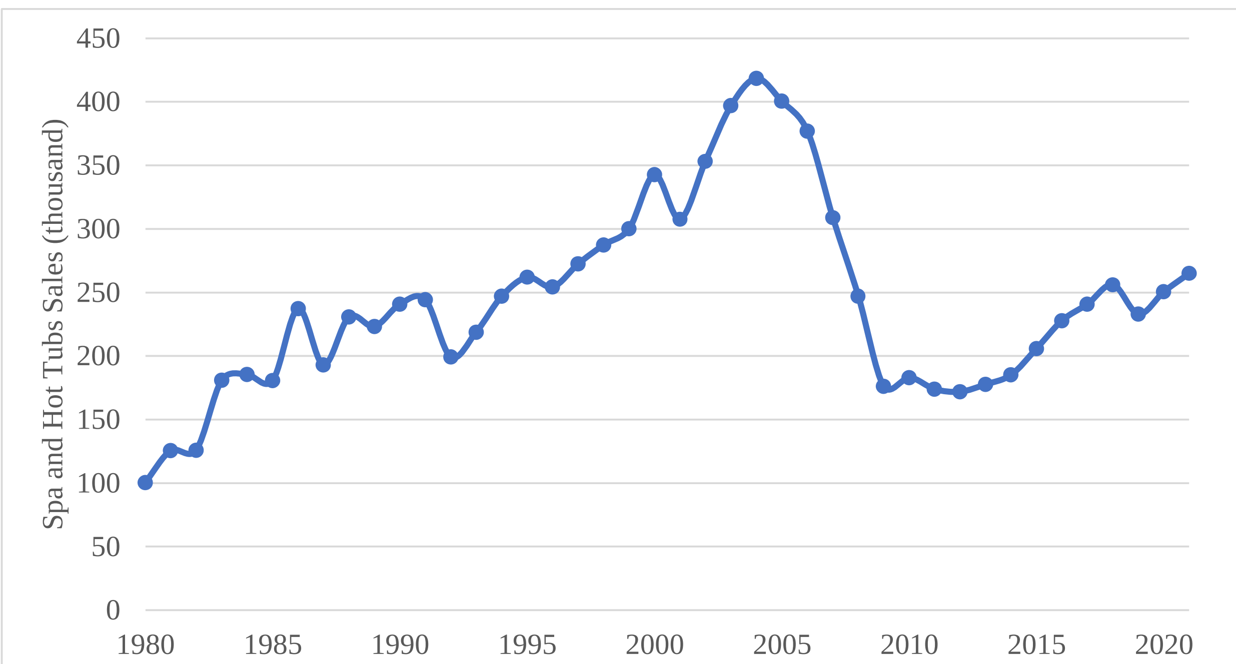

Figure 9.3.4 **Estimated Historical Shipments of Residential Spas and Hot Tubs, 1980–2021**

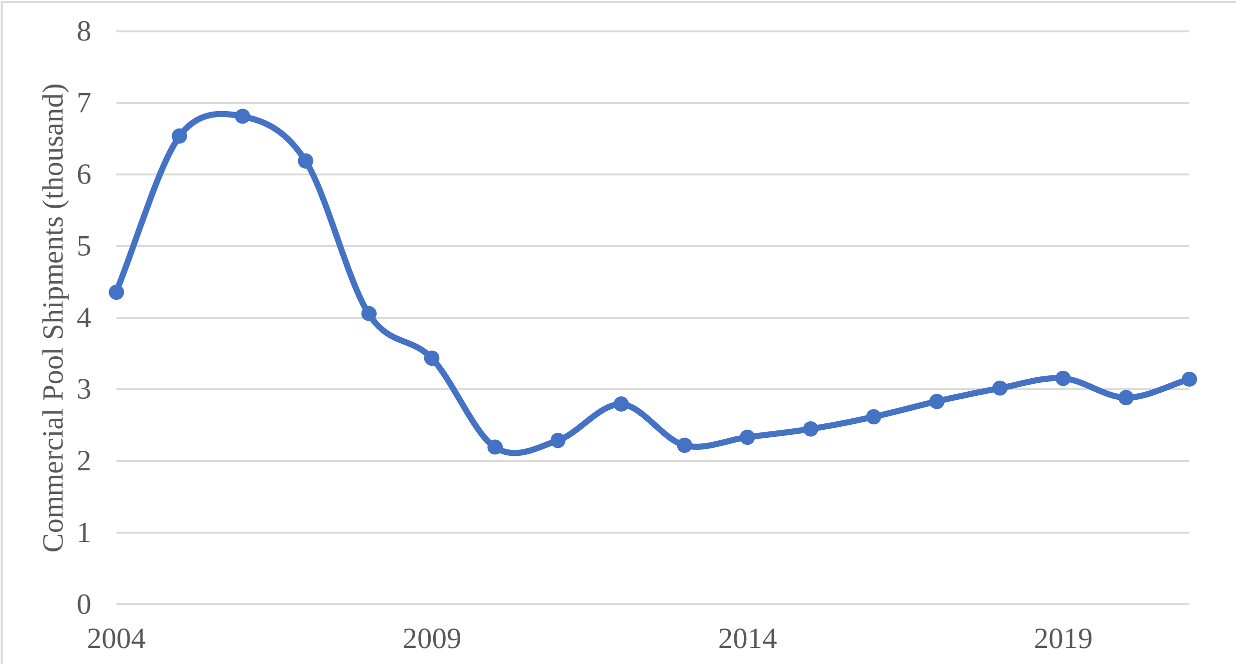

Figure 9.3.5 Estimated Historical Shipments of Commercial Swimming Pools, 2004–2021

9.3.3 Historical Pool Heaters Saturations in New Swimming Pools and Spas

DOE estimated the historical fractions of consumer pool heaters in installed in new swimming pools and spas based on data from multiple Pkdata reports,[4,5,6,7] Energy Information Administration (EIA)'s 1990–2020 Residential Energy Consumption Survey (RECS),[8] and EIA's 2012 and 2018 Commercial Building Energy Consumption Survey (CBECS).[9,10]

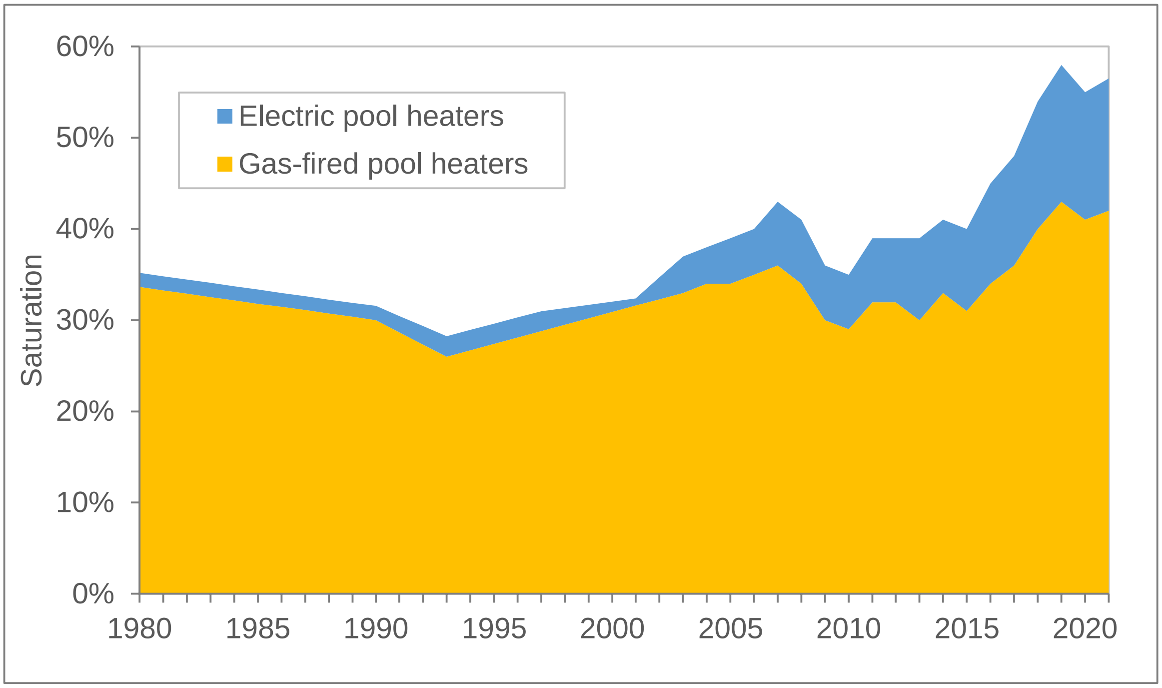

Figure 9.3.6 Estimated Historical Pool Heaters Saturations for New Residential Inground Pool Constructions, 1980-2021

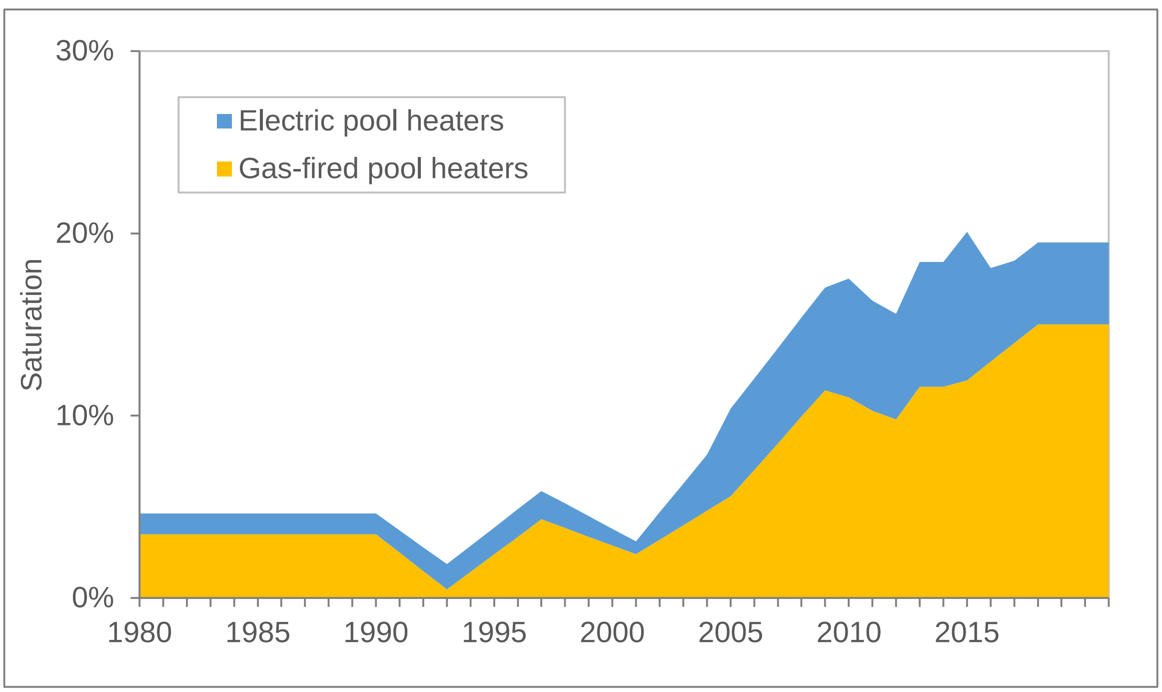

Figure 9.3.7 Estimated Historical Pool Heaters Saturations for New Residential Aboveground Pool Sales, 1980-2021

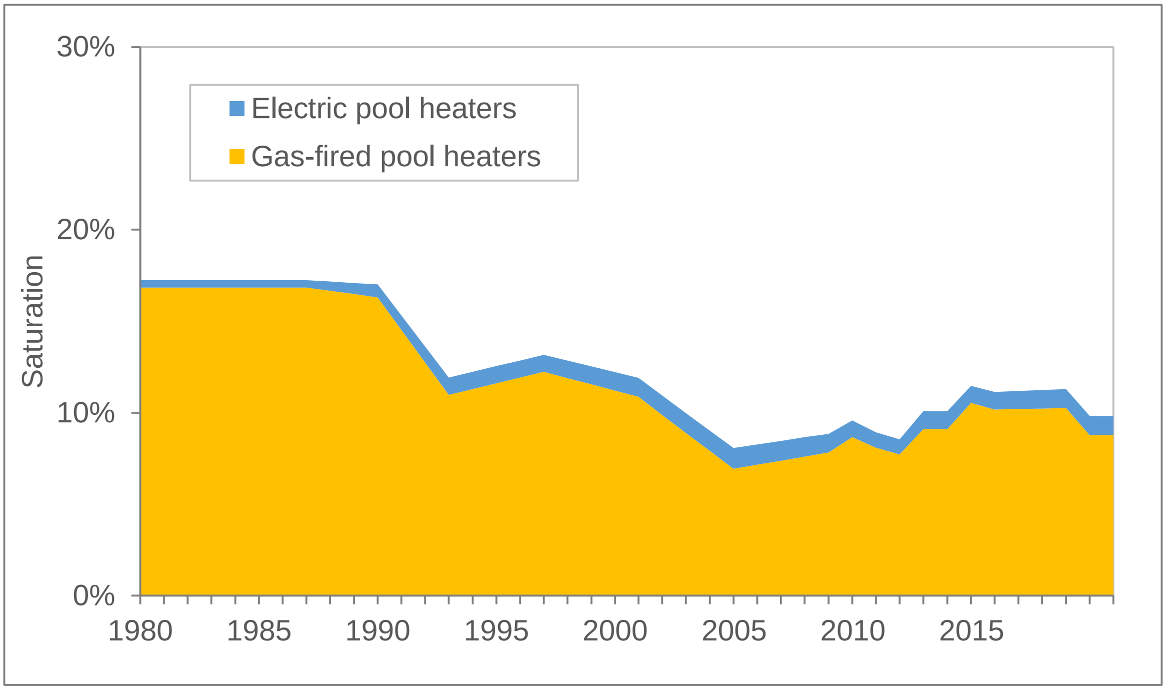

Figure 9.3.8 Estimated Historical Pool Heaters Saturations for New Residential Spa and Hot Tub Sales, 1980-2021

For consumer pool heaters installed in new spas in the commercial sector, DOE used 2022 Pkdata to estimate the fraction of commercial swimming pool with a pool heater. Based on this data estimated this fraction to be 64 percent in 1980 to 2003 and then rise up to 67 percent in 2021. The For consumer pool heaters installed in new spas in the commercial sector, DOE assumed that of the swimming pools installed with a pool heater 19 percent would be electric pool heaters and 81 percent would be gas-fired pool heaters based on CBECS 2012 data ratio of electric to gas-fired pool heaters for commercial indoor swimming pools. For consumer pool heaters installed in new spas in the commercial sector, DOE assumed that all would be installed with a consumer pool heater and 9.5 percent would be electric pool heaters and 90.5 percent would be gas-fired pool heaters (in other words, DOE assumed half the fraction of electric pool heaters installed in new commercial swimming pools). In addition, DOE estimated that 50 percent of consumer shipments to new commercial swimming pools and spas would install two pool heaters. DOE based its estimate of the new swimming pool stock on historical shipments of new pools and past fraction of these shipments with a consumer pool heater.

9.3.4 Historical Pool Heater and Swimming Pool and Spa Stock Data

DOE was also able to gather swimming pool and spa stock data from 1990–2020 RECS and 2022 Pkdata. The data was used to calibrate the shipments model and to estimate new owner pool heater shipments. See appendix 8G for all historical data.

9.3.5 Historical New Owners Factor

As described in the section 9.2.3 equations of DOE's shipments model, DOE forecast new owners[b] in existing swimming pools or spas that did not previously have a consumer pool heater or switch consumer pool heater types by multiplying the stock of swimming pool and spa owners that do not currently have a pool heater by the new pool owner factor. The swimming pool and spa historical stock DOE used 1990-2020 RECS and 2022 Pkdata. For residential applications, DOE estimated the new owner factor varies from 0.01 percent in 1980 to 0.50 percent in 2021 for electric pool heaters and varies from 0.16 in 1980 to 0.09 in 2019 percent for gas-fired pool heaters, based on historical shipments modeling. For commercial applications, DOE estimated that the new owner factor varies from 0.59 percent to 0.002 percent for electric pool heaters and varies from 2.53 percent in 1980 to 0.008 percent for gas-fired pool heaters, based on historical shipments modeling. DOE assumes that for both residential and commercial sectors, the new owner factor decreases overtime as the market for swimming pools and spas becomes more saturated. DOE estimated an increasing and higher saturation of EPHs compared to GPHs due to the shipments growth of heat pump pool heaters.

9.3.6 Historical Non-Replacement Fraction

DOE determined that a fraction of owners of pool heaters do not replace the product when it fails. Reasons for non-replacement include high cost of operating the pool heater, change in the consumer needs, difficulties in maintaining and operating the pool heater, swimming pool, or spa, demolition of the swimming pool or spa. DOE estimated that the non-replacement factor to vary significantly overtime from 14 percent in 1980, 49 percent in 1990, 7 percent in 2005, 54 percent in 2009, and 17 percent in 2019 (with an average during this period of 34 percent) for consumer pool heaters in residential applications (in other words, on average 66 percent of consumer pool heaters in residential applications were are replaced on average). DOE estimated that the factor would vary significantly in the residential market as residential consumers were more likely to not replace their equipment for the reasons above and were more susceptible to changes in economic conditions. For consumer pool heaters in commercial applications, DOE estimated that 2 percent of consumer pool heaters that were retired were not replaced (in other words 98 percent of consumer pool heaters in commercial applications were replaced).

9.3.7 Survival Function for Pool Heaters

As described in appendix 8F, DOE defined lifetime as the age when a product is retired from service and uses survival function to model the probability distribution of retirements of the product. The survival function, which is assumed to have the form of a cumulative Weibull distribution, was developed based on a method using shipments and survey data to estimate the distribution of consumer pool heater lifetimes in the field. The resulting Weibull distribution results in average lifetime value of 11.0 years. The survival function used for the analysis is shown in Figure 9.3.9.

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[b] The new owners market segment refers to existing pool owners that install a new pool heater as well as existing pool owners that switch from a pool heater of different fuel type.

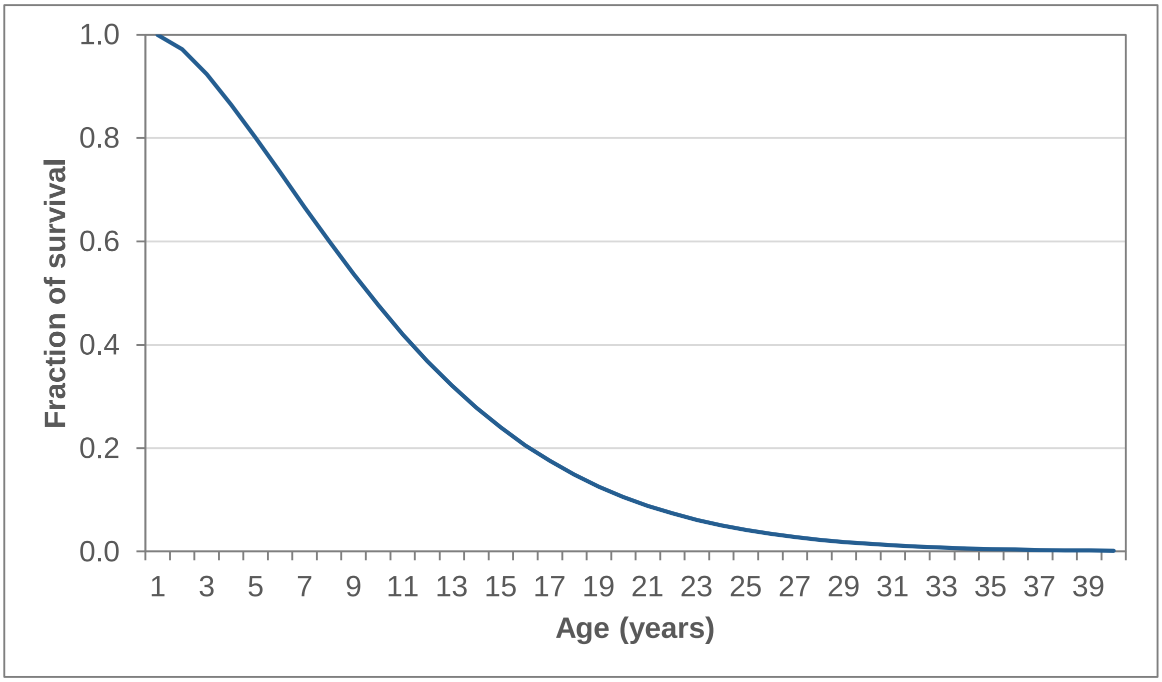

Figure 9.3.9 Survival Function for Electric and Gas-fired Pool Heaters

9.4 FORECASTED POOL HEATER SHIPMENTS (NO-NEW-STANDARDS)

9.4.1 Forecast of Pool Heater Shipments to Replacements

As described in the section 9.2.2 equations of DOE's shipments model, DOE estimated replacement shipments using the product survival function, existing products in the stock, and non-replacement factor, as follows:

Pool heater survival function: Depending on the vintage, a certain percentage of consumer pool heaters will fail and be replaced. To determine when a unit fails, DOE used a survival function based on a distribution of product lifetimes having an average value of 10.6 years (see section 9.3.7).

Pool heater stock: DOE estimated the existing stock of products using estimated historical shipments (see section 9.3.1) and survival function for consumer pool heaters.

Pool heater non-replacement factor: DOE took into account non-replacement rate of retired (failed) residential consumer pool heaters. For its forecast period from 2026 to 2055, DOE estimated that 35 percent of consumer pool heaters in residential applications and 2 percent of consumer pool heaters in commercial applications that are retired are not replaced (in other words 65 percent of consumer pool heaters in residential applications and 98 percent of consumer pool heaters in commercial applications are replaced).

9.4.2 Forecast of Pool Heaters in New Swimming Pools and Spas

As described in the section 9.2.3 equations of DOE's shipments model, DOE estimated consumer pool heater shipments installed in new swimming pools and spas by multiplying forecasted new swimming pools and spas by forecasted consumer pool heater saturations from 2026-2055. DOE's derivation of forecasts for new swimming pools and spas is described in section 9.4.2.1. DOE' derivation of saturations of consumer pool heaters in new swimming pools and spas is described in 9.4.2.2.

9.4.2.1 Forecast of New Swimming Pools and Spas

DOE estimated project installations and shipments to new swimming pools and spas by first historical swimming pool and spa data and correlating this data to macroeconomic parameters (such as single-family housing starts, income per capita, new commercial square footage) to develop regression formulas. The resulting regression formulas were then used, together with projected macroeconomic data, to forecast installations and shipments to new swimming pools and spas.

The analysis of historical swimming pool and spa data from section 9.3.2 showed that the overall trends of new residential inground pool constructions, aboveground pool sales, and spas and hot tubs were related to historical single-family housing starts[11] (especially after 1980s for inground pools and after 1990s for aboveground pools) and real disposable personal income per capita[c] (see Figure 9.4.1 through Figure 9.4.3). In addition, new commercial pools were related to new commercial floor space (see Figure 9.4.4).[d]

[c] Calculated by dividing real disposable personal income[12] by population.[13]

[d] Note that DOE did not have any data regarding new commercial spas installations, so DOE assumed that commercial spas installations are equivalent to 50 percent of new commercial swimming pool installations.

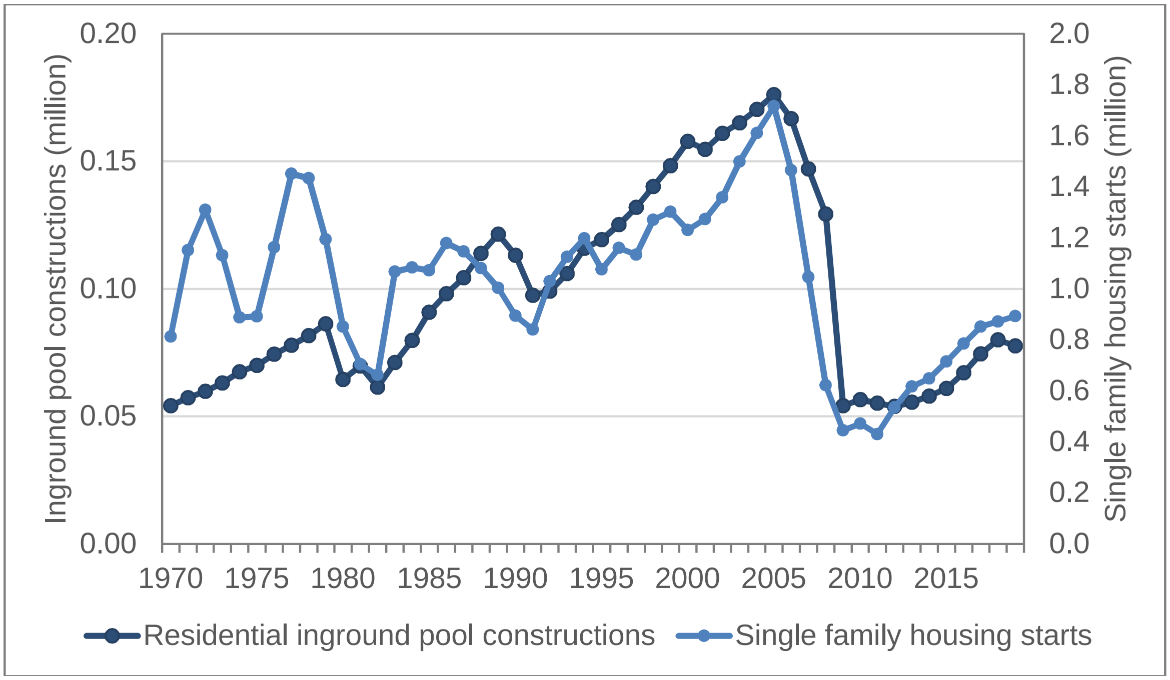

Figure 9.4.1 Estimated Historical Residential Inground Pool Constructions and Single-family Housing Starts, 1970–2021

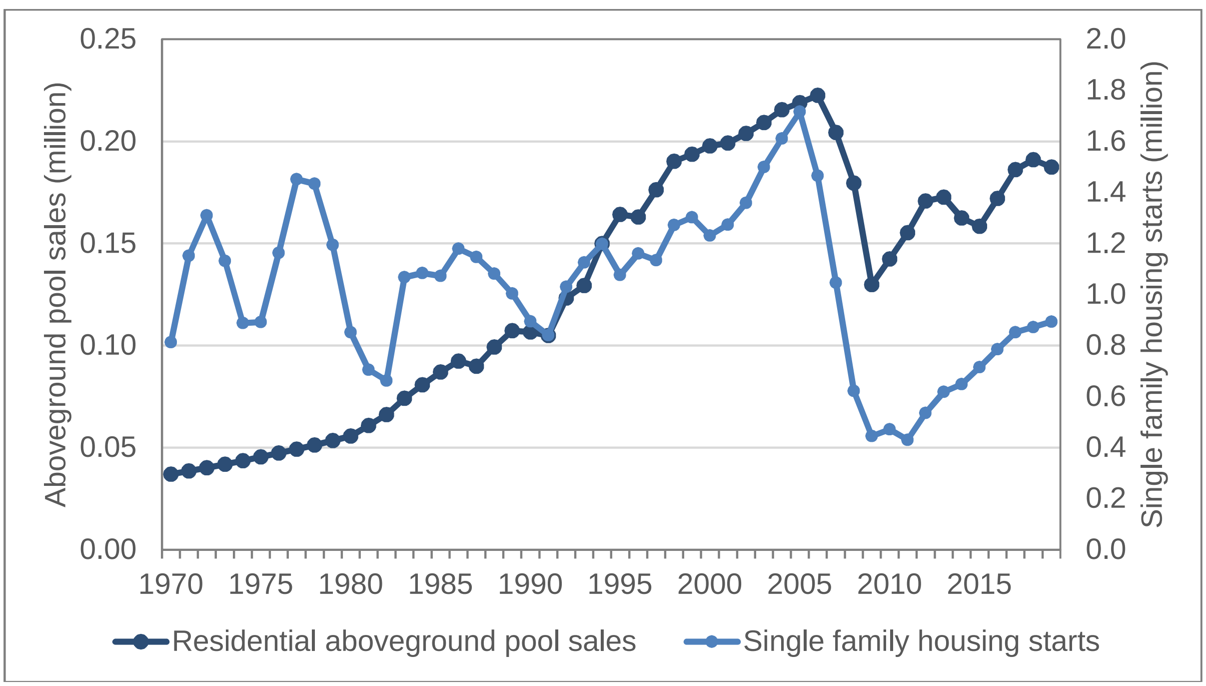

Figure 9.4.2 Estimated Historical Residential Aboveground Pool Sales and Single-family Housing Starts, 1970–2021

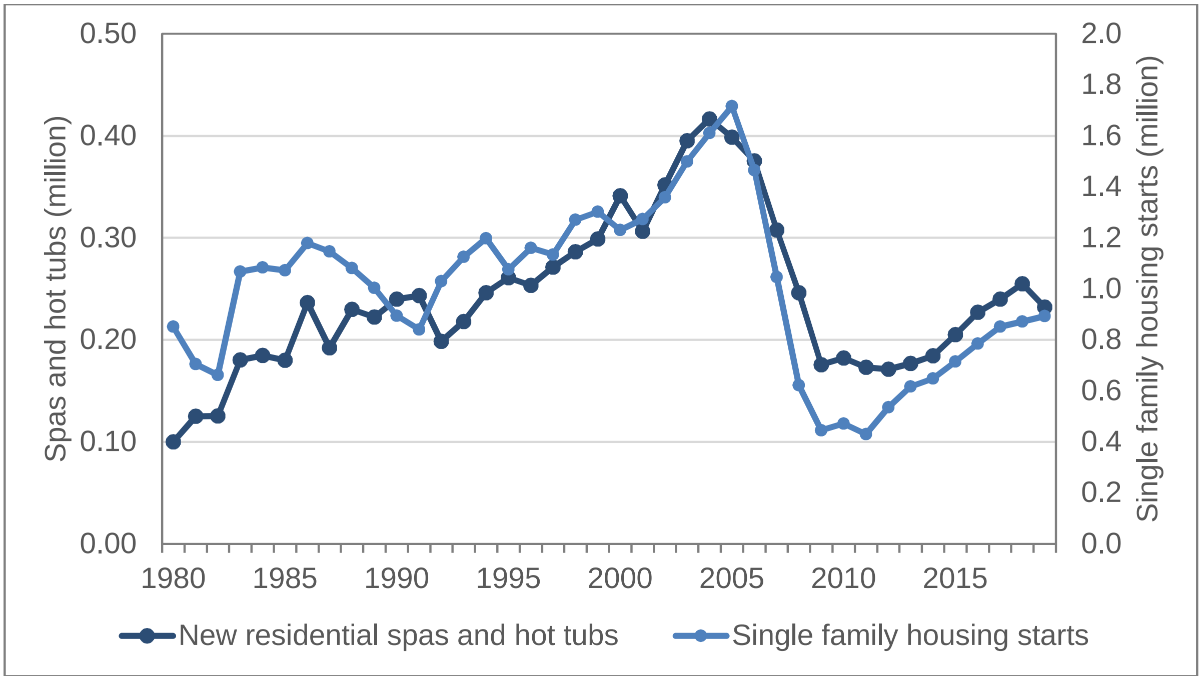

Figure 9.4.3 Historical Shipments of Residential Spas and Hot Tubs and Single-family Housing Starts, 1980–2021

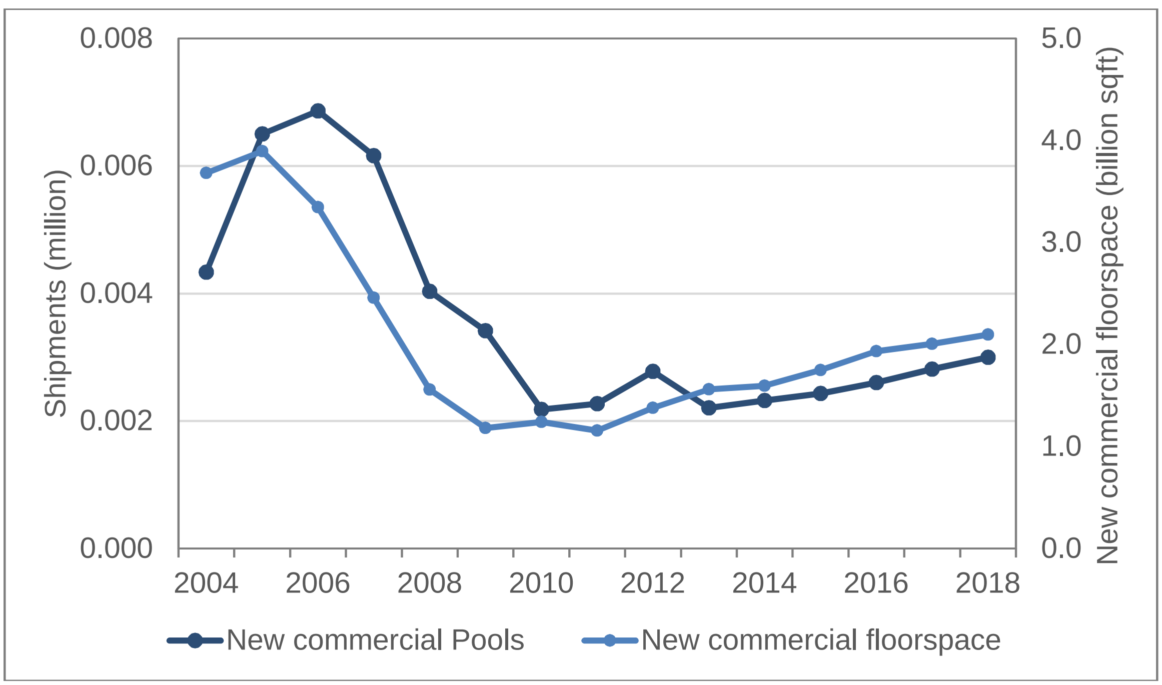

Figure 9.4.4 Historical Shipments of Commercial Swimming Pools and New Commercial Floor Space, 2004–2021

DOE used projected 2022-2050 data for single family housing starts, population, real disposable personal income per capita,[e] and commercial floor space derived from EIA's Annual Energy Outlook 2022 with Projections to 2050 (AEO 2022).[14] From 2051-2055, DOE assumed a constant value equal to the 2050 value from AEO 2022 for single family housing starts and new additions to commercial floorspace. DOE assumed that the real disposable personal income and population growth would follow their trends in 2045-2050 after 2050. Figure 9.4.5 through Figure 9.4.8 show the projected single-family housing starts, real disposable personal income per capita, and new additions to commercial floorspace from 2022 to 2055.

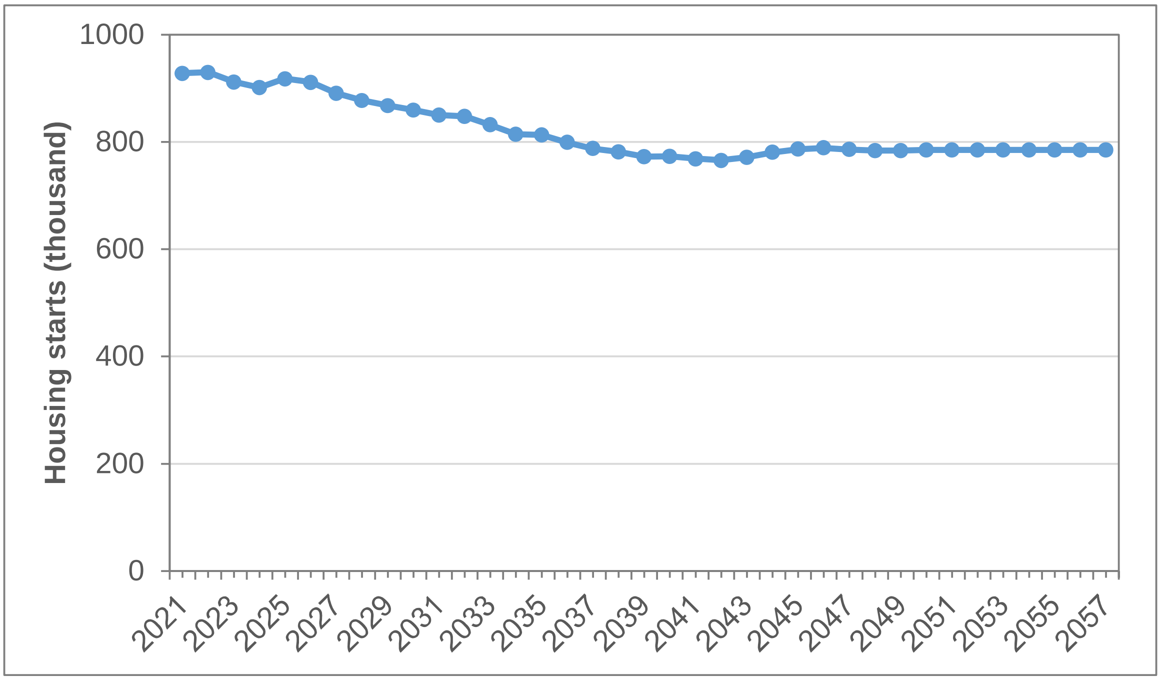

Figure 9.4.5 Projected Single Family Housing Starts, 2022–2057

[e] Calculated by dividing real disposable personal income by population.

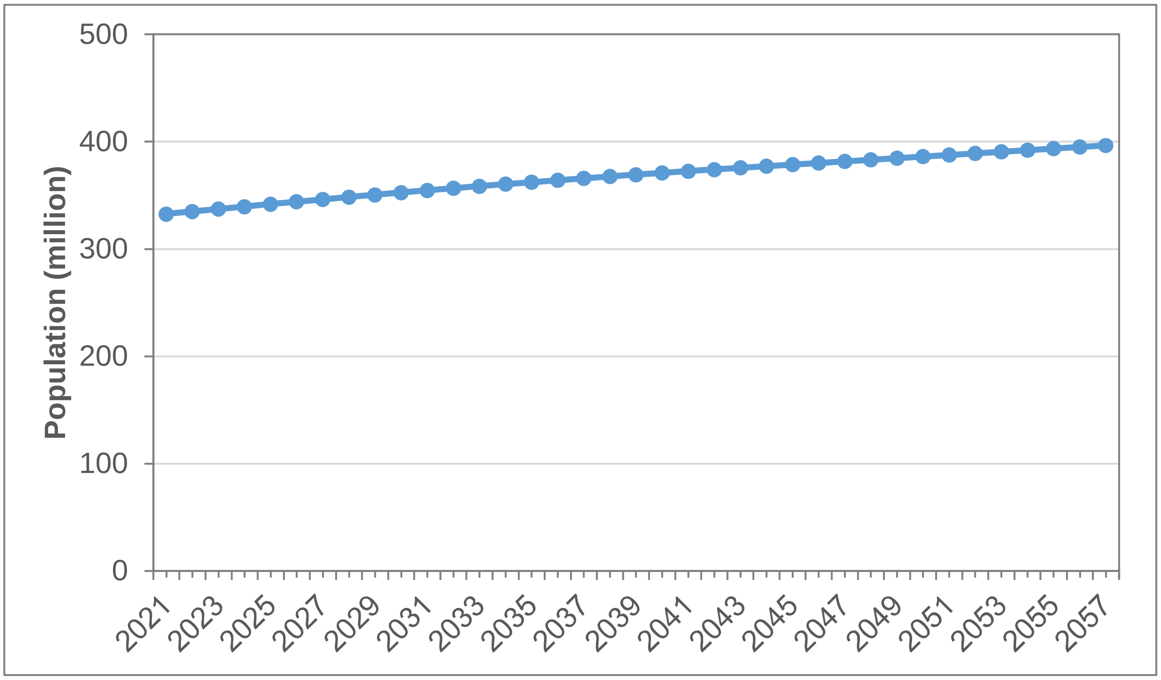

Figure 9.4.6 Projected Population, 2022–2057

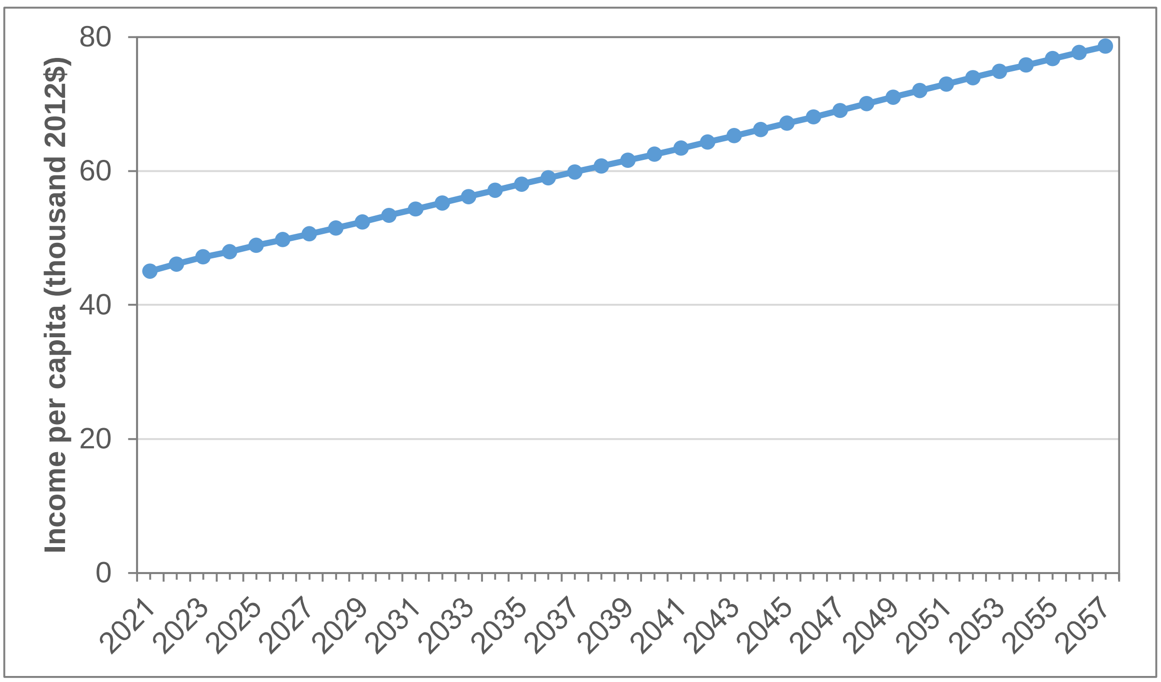

Figure 9.4.7 Projected Real Disposable Personal Income per Capita, 2022–2057

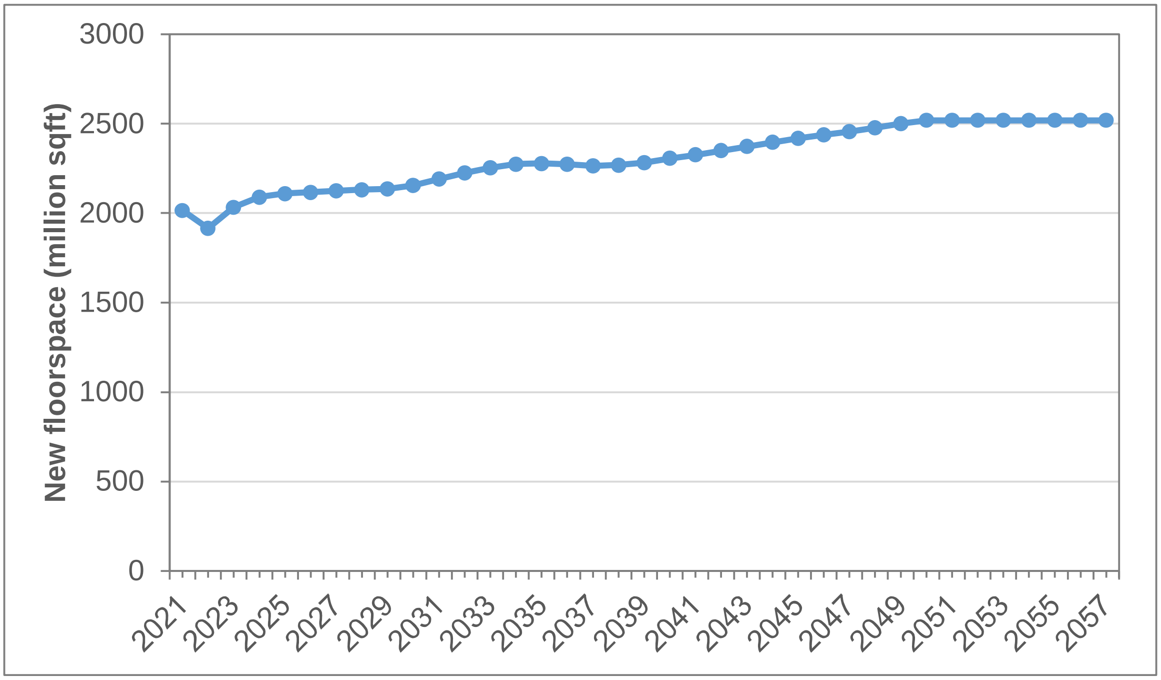

Figure 9.4.8 Projected New Additions to Commercial Floorspace, 2022–2057

DOE assumed that the swimming pool market would level off around 2026–2027 and applied the regression formulas to project the swimming pool shipments by then. DOE assumed that pool shipments would level off around 2026–2027 based on historical and current market trends and a recent article that indicated that pool constructions were not expected to reach historical highs or increase rapidly and significantly in the future.[15] The pool shipments are interpolated using sigmoid curve (which offers smooth transition between data points) for shipments between the last historical data point and start year for the regression formula.

Figure 9.4.9 through Figure 9.4.12 show DOE's forecast for new swimming pools and spas from 2022-2055, as well as the historical data prior to 2021.

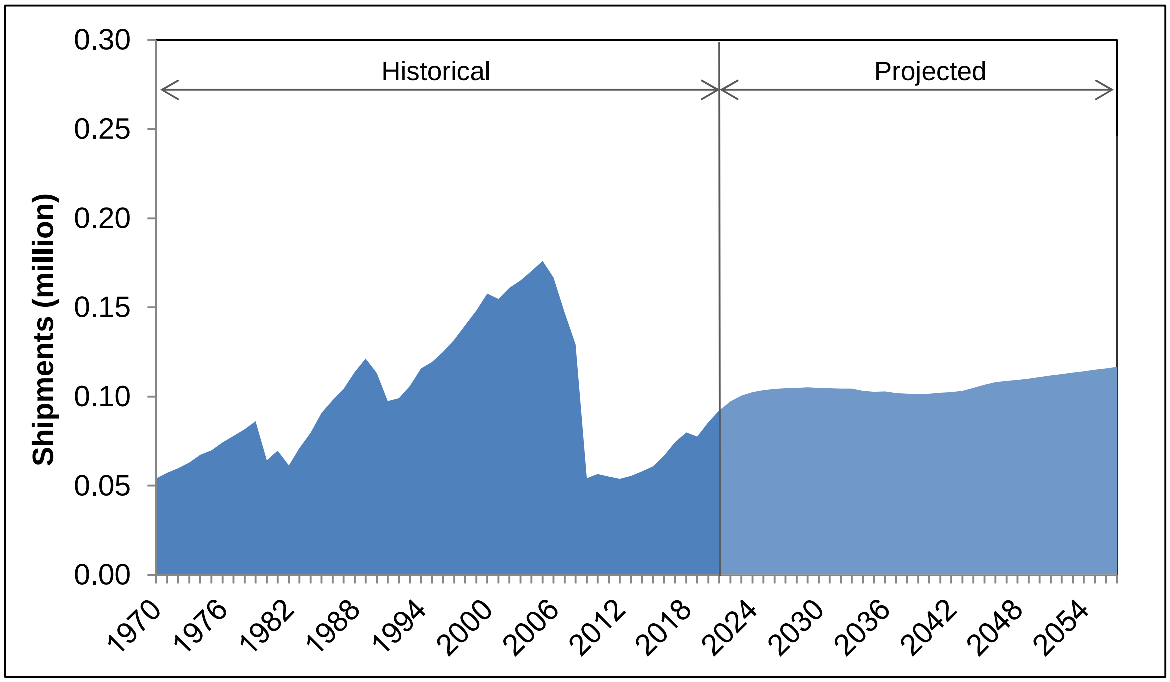

Figure 9.4.9 Historical and Projected New Residential Inground Swimming Pool Constructions

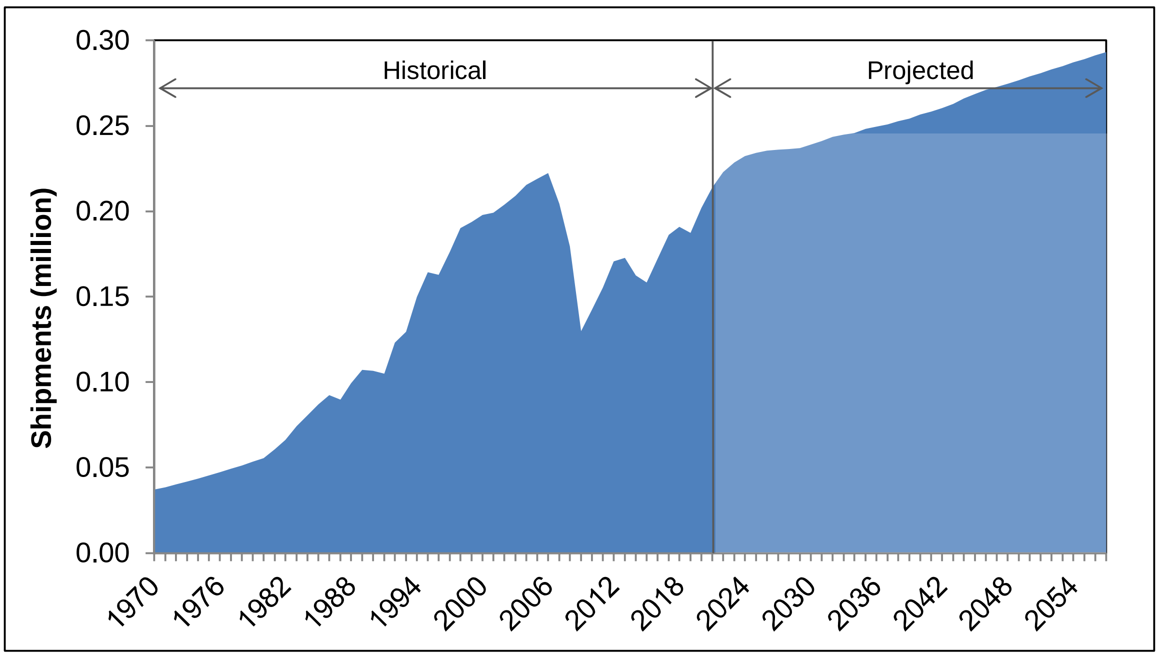

Figure 9.4.10 Historical and Projected Shipments of Residential Aboveground Swimming Pools

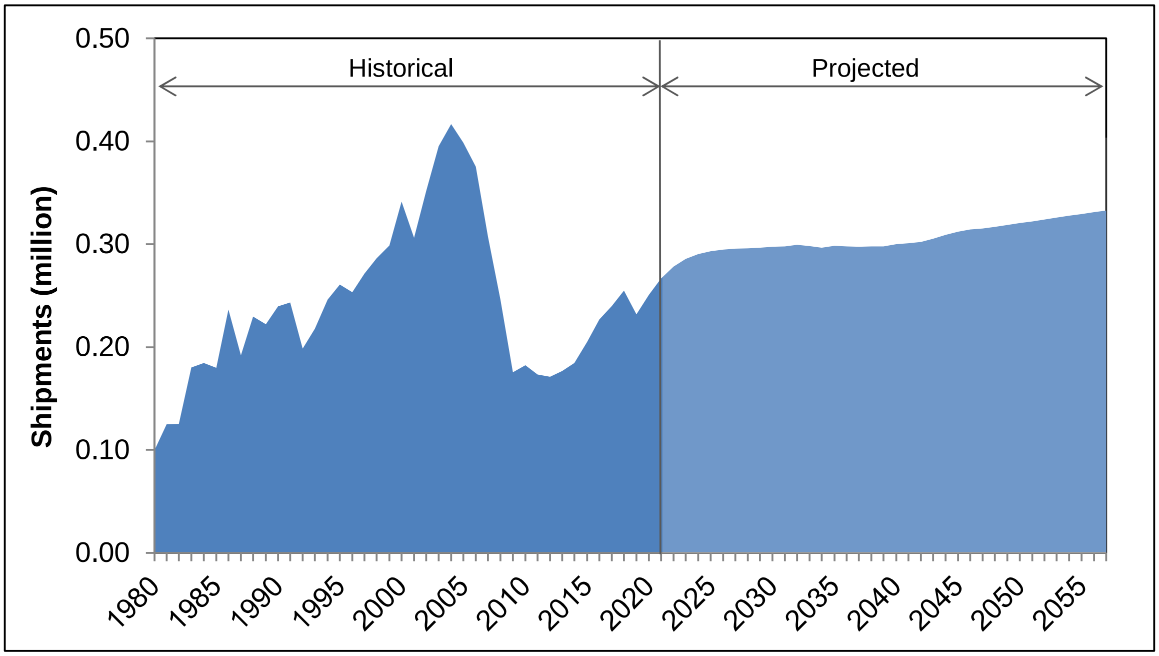

Figure 9.4.11 Historical and Projected Shipments of Residential Spas and Hot Tubs

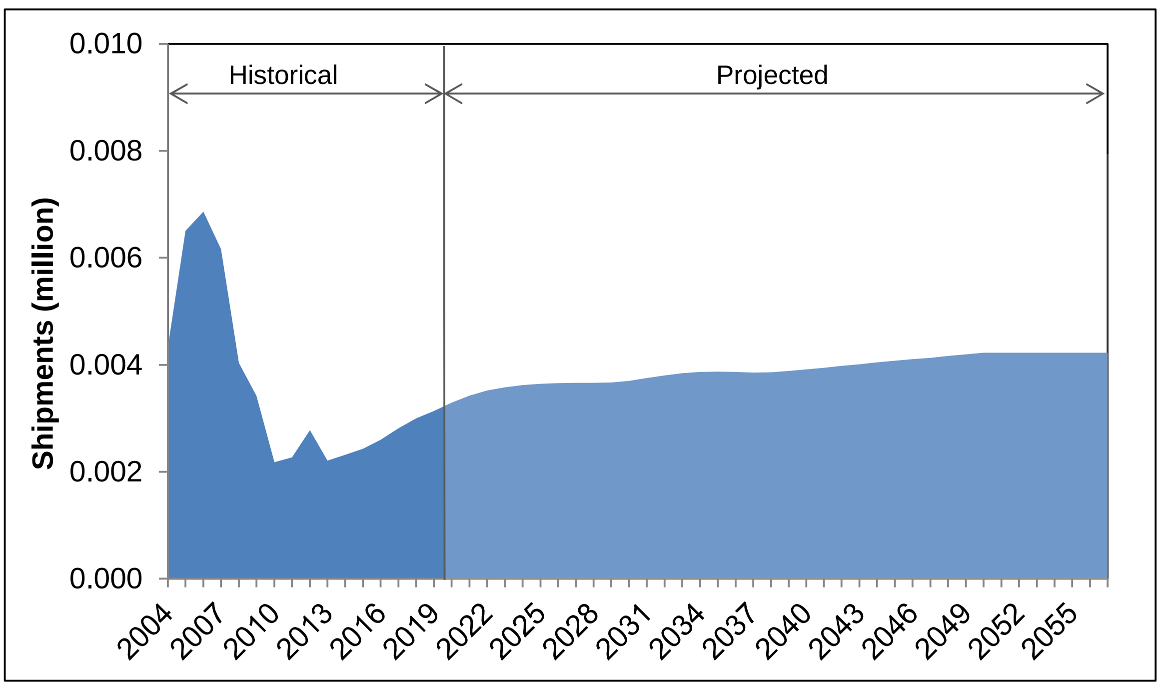

Figure 9.4.12 Historical and Projected New Commercial Swimming Pool Constructions

9.4.2.2 Pool Heater Saturations in New Swimming Pools and Spas

DOE forecast the saturation rates for consumer pool heaters in new swimming pools and spas based on historical trends (see section 9.3.3). Table 9.4.1 summarizes the derivation of the forecast saturations by new swimming pool and spa market type. Based on 2022 Pkdata,[4] 1990-2020 RECS,[8] and CBECS 2012 and 2018 data.[9,10]

Table 9.4.1 Consumer Pool Heater Saturation Fractions in New Swimming Pools and Spas in 2028 and Assumptions

Swimming Pool and Spa Market Type	2028 Saturation, %			Assumptions
	EPH	GPH	Total	
New Residential Inground Swimming Pools	18	43	61	EPH increases by 0.34%/yr* starting from 15% in 2021.† GPH value is held constant based on 2021 data.†
New Residential Aboveground Swimming Pools	9	12	21	Total value is held constant based on 2021 data.† EPH increases by 0.34%/yr* starting from 6% in 2021.† GPH decreases by 0.34%/yr* starting from 15% in 2021.†
New Residential Spa	1.5	12	13	EPH and GPH values based on RECS data.**
New Commercial Swimming Pool	14	58	72	Total increases by 0.43%/yr starting from 69% in 2021.† EPH and GPH ratio held constant at 19% to 81% of total.††
New Commercial Spa	9	91	100	Total value is held constant. EPH and GPH ratio held constant at 9% to 91% of total.††

* 20 percent of the growth for new residential inground swimming pools based on 2022 Pkdata.
** Based on 1990-2020 RECS data
† Based on 2022 Pkdata.
†† Based on CBECS 2012 and 2018 data ratio of electric to gas-fired pool heaters. For commercial spas, DOE assumed half the fraction of electric pool heaters.

In addition, for the commercial sector, DOE estimated that 50 percent of consumer shipments to new commercial swimming pools and spas would install two pool heaters. DOE based its estimate of the new swimming pool stock on historical shipments of new pools and past fraction of these shipments with a consumer pool heater.

9.4.3 Forecast of Pool Heater Shipments to New Owners

As described in the section 9.2.3 equations of DOE's shipments model, DOE forecast new owners[f] in existing swimming pools or spas that did not previously have a consumer pool heater or switch consumer pool heater types by multiplying the stock of swimming pool and spa owners that do not currently have a pool heater by the new pool owner factor. The swimming pool and spa stock is calculated by shipments model using new swimming pool and spa installations and assuming very low demolition rates of existing pools and spas. For residential applications, DOE estimated the new owner factor is equal to 0.14 percent for electric pool heaters and 0.07 percent for gas-fired pool heaters, based on historical trends. For commercial applications, DOE estimated that the new owner factor is equal to 0.002 percent for electric and 0.008 percent for gas-fired pool heaters, based on historical trends. See section 9.3.5 for more discussion about historical trends.

9.5 IMPACT OF ENERGY CONSERVATION STANDARDS ON SHIPMENTS

For replacements, consumer decisions to purchase or repair a pool heater are influenced by the purchase price and operating cost of the product, and therefore may be different in the no-

[f] The new owners market segment refers to existing pool owners that install a new pool heater as well as existing pool owners that switch from a pool heater of different fuel type.

new-standards case and under standards cases at different efficiency levels (ELs).[g] These decisions were modeled by estimating the purchase price elasticity for pool heaters. The purchase price elasticity is defined as the change in the percentage of consumers acquiring a pool heater divided by a change in the *relative price* (defined below) for that product. This elasticity, along with information obtained from the life-cycle cost (LCC) and payback period (PBP) analysis on the change in purchase price and operating costs at different ELs, are used in the shipments model to estimate the change in shipments under potential standards at different ELs.

DOE used a study that conducted a literature review and an analysis of appliance price and efficiency data to estimate the effects on product shipments from increases in product purchase price and product energy efficiency.[16]

Existing studies of appliance markets suggest that the demand for durable goods, such as appliances, is price-inelastic. Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for appliances, and that consumer behavior reflects relatively high implicit discount rates[h] when comparing appliance prices and appliance operating costs.

The study used the available data for the period 1989-2009 on household appliance purchases to evaluate broad market trends and conduct simple regression analyses. These data indicate that there has been a rise in appliance shipments and a decline in appliance purchase price and operating costs over the time period. Other relevant variables include household income, which has also risen during this time, new residential construction, and stock failures of existing appliances. Using these data, the study performed a regression analysis to estimate two parameters, the price elasticity of appliance demand and the shipments response to appliance efficiency, defined as follows:

$$\varepsilon_d = \frac{\frac{\Delta q}{q}}{\frac{\Delta p}{p}}$$

Eq. 9.10

Where:

ε_d = price elasticity of demand,
q = quantity of shipments, and

[g] Because the percentage change in the cost of pool heaters due to amended pool heater standards is relatively small, DOE assumed that the new construction market is unaffected by changes in either the total installed cost or operating costs of the product. That is, home builders are not likely to choose to not install a pool heater if the installed cost rises by a small amount.

[h] An implicit discount rate refers to a rate than can be inferred from observed consumer behavior with regard to future operating cost savings realized from more-efficient appliances. An implicit discount rate is not a true discount rate because the observed consumer behavior is affected by lack of information, high transaction costs, and other market barriers. However, implicit discount rates can predict consumer purchase behavior with respect to energy-efficient appliances. A high implicit discount rate with regard to operating costs means that consumer reflects a high discounting of future operating cost savings realized from more-efficient appliances. In other words, consumers are much more concerned with higher purchase prices.

p = price

$$\varepsilon_e = \frac{\frac{\Delta q}{q}}{\frac{\Delta e}{e}}$$

Eq. 9.11

Where:

ε_e = "efficiency elasticity",
q = quantity of shipments, and
e = product efficiency.

The regression analysis suggests that the price elasticity of demand, based on aggregated data for five residential appliances, is -0.45. Thus, for example, a price increase of 10 percent would result in a shipments decrease of 4.5 percent, *all other factors held constant*. The efficiency elasticity is estimated to be +0.2 (*i.e.*, a 10 percent efficiency improvement would result in a shipments increase of 2%, *all else equal*).[i]

The price elasticity estimate of -0.45 is consistent with estimates of appliance and durables price effects in the literature. Nevertheless, the study stresses that the measure is based on a small data set, using simple statistical analysis. More importantly, the measure is based on the assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States between 1989 and 2009. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE did not account for them in this analysis. Despite the uncertainties, DOE believes that its estimates provide a reasonable assessment of the effect that purchase price and efficiency have on product shipments.

Because DOE's projections of shipments and national impacts from potential standards consider a 30-year period, DOE needed to consider how price elasticity evolves in the years after a new standard takes effect. DOE considered the price elasticity developed above to be a short-term value, but was unable to identify sources specific to appliances sufficient model differences in short- and long-term price elasticities. Therefore, to estimate how the price elasticity changes through time, DOE relied on a study pertaining to automobiles.[17] This study shows that the price elasticity of demand for automobiles changes in the years following a change in purchase price, a trend also observed in appliances and other durables.[18,j] As time passes since the change in purchase price, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change. Table 9.5.1 shows the relative change over time in the price elasticity of demand for automobiles. As shown in the table, DOE developed a time series of price elasticity for residential appliances based on the relative change over time in the

[i] Note that DOE previously combined these impacts in a variable termed "relative price elasticity." Price and efficiency impacts are now separated for greater consistency with price elasticity measures reported in the literature.
[j] DOE relies on Hymens et al. (1970) for efficiency scaling factors because it provides the greatest detail out of the available studies on price elasticity over time.[17]

price elasticity of demand for automobiles. For years not shown in the table, DOE performed a linear interpolation to obtain the price elasticity.

Table 9.5.1 Change in Price Elasticity and Efficiency Elasticity Following a Purchase Price Change

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Relative Change in Elasticity to first year	1.00	0.78	0.63	0.46	0.35	0.33
Price Elasticity	-0.45	-0.35	-0.28	-0.21	-0.16	-0.15
Efficiency Elasticity	0.20	0.16	0.13	0.09	0.07	0.07

Using the following equation, DOE estimated standards-case shipments by considering the effect of price and efficiency. Note that in the equation below, the *price*, the *price* elasticity, the *efficiency*, and the *efficiency elasticity* are functions of the year because they change with time.

$$dRS_p(j) = \max\left[|\varepsilon_d(j)| \times \Delta P_p(j) - |\varepsilon_e(j)| \times \Delta E_p(j) \, , 0 \right]$$

Eq. 9.12

Where:

$dRS_p(j)$ = percentage replacement shipments drop for product class *p* in year *j*,

$\varepsilon_d(j)$ = price elasticity in year *j* (equals -0.45 for year 1),

$\Delta P_p(j)$ =change in price due to a standard level for product class *p* in year *j*, %

$\varepsilon_e(j)$ = efficiency elasticity in year *j* (equals 0.20 for year 1), and

$\Delta E_p(j)$ = change in efficiency due to a standard level for product class *p* in year *j*, %.

9.5.1 Impact of Standards on Equipment Switching

DOE looked at the potential for equipment switching due to potential standards. For example, if electric pool heater standard is set such that electric resistance heaters are removed from the market, it is possible that a portion of consumers would shift to natural gas or propane pool heaters due to lower first costs or other considerations (such as faster heat recovery compared to a heat pump pool heater). Similarly, if the gas-fired pool heater standard is set high enough it is possible that a portion of consumers would shift to electric pool heaters. DOE reasoned that costs associated with switching from an electric pool heater to a gas-fired pool heater (such as extending the gas line, adding a propane tank, or accounting for venting) or gas-fired pool heater to an electric pool heater (such as upgrading electric connection or upgrading electrical panel) would tend to limit such switching. In addition, for this NOPD, DOE mainly considered the highest efficiency levels where the proposed increases in gas-fired pool heater efficiency standards would increase the efficiency and/or costs proportionally to the increase in efficiency and/or costs of the electric pool heaters efficiency standards. Therefore, for this analysis, DOE did not consider the potential impact of consumers opting to switch from an electric pool heater to a gas-fired pool heater or from gas-fired pool heaters to electric pool heaters in response to the evaluated standards.

9.6 RESULTS

This section provides results shipments results for no-new-standards and standard cases. As detailed in chapter 10, DOE created trial standard levels (TSLs) that combine specific efficiency levels (ELs) across product classes. Table 9.6.1 presents the TSLs and the corresponding efficiency levels for electric pool heaters and gas-fired pool heaters.

Table 9.6.1 Trial Standard Levels for Proposed Consumer Pool Heater Standards

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
	Representative TE_I (%)					
Electric Pool Heaters	387	483	534	551	551	595
Gas-fired Pool Heaters	81.3	81.3	81.3	81.3	83.3	94.8
	Efficiency Level					
Electric Pool Heaters	1	2	3	4	4	5
Gas-fired Pool Heaters	1	1	1	1	2	3

9.6.1 No-New-Standards Case Shipments

Figure 9.6.1 shows the projected no-new-standards case shipments of electric pool heaters by market segment. Figure 9.6.2 shows the projected no-new-standards case shipments of gas-fired pool heaters by market segment. Figure 9.6.3 shows the historical and projected shipments for pool heaters.

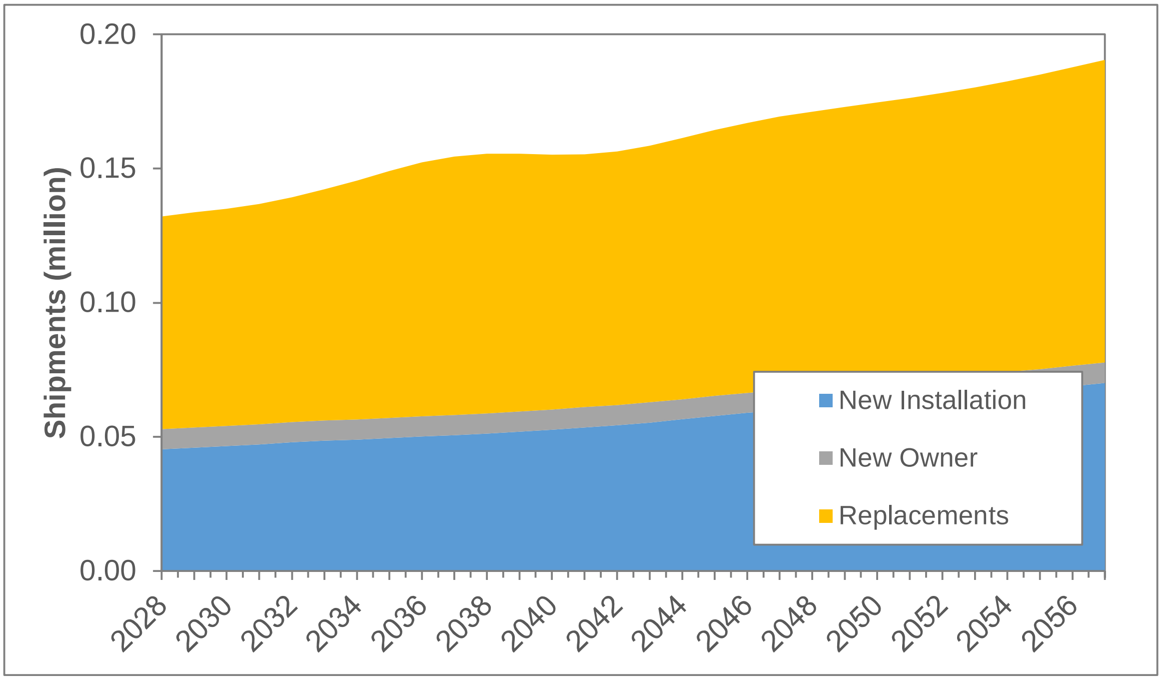

Figure 9.6.1 Projected No-New-Standards Case Shipments of Electric Pool Heaters by Market Segment, 2028-2057

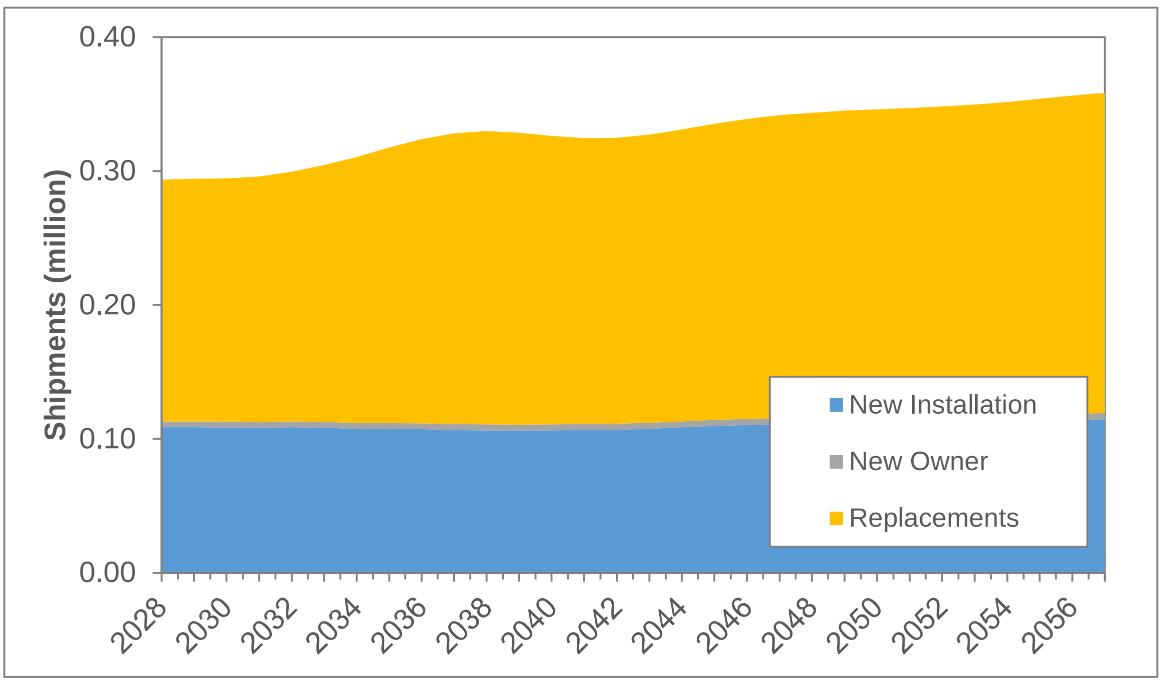

Figure 9.6.2 Projected No-New-Standards Case Shipments of Gas-Fired Pool Heaters by Market Segment, 2028-2057

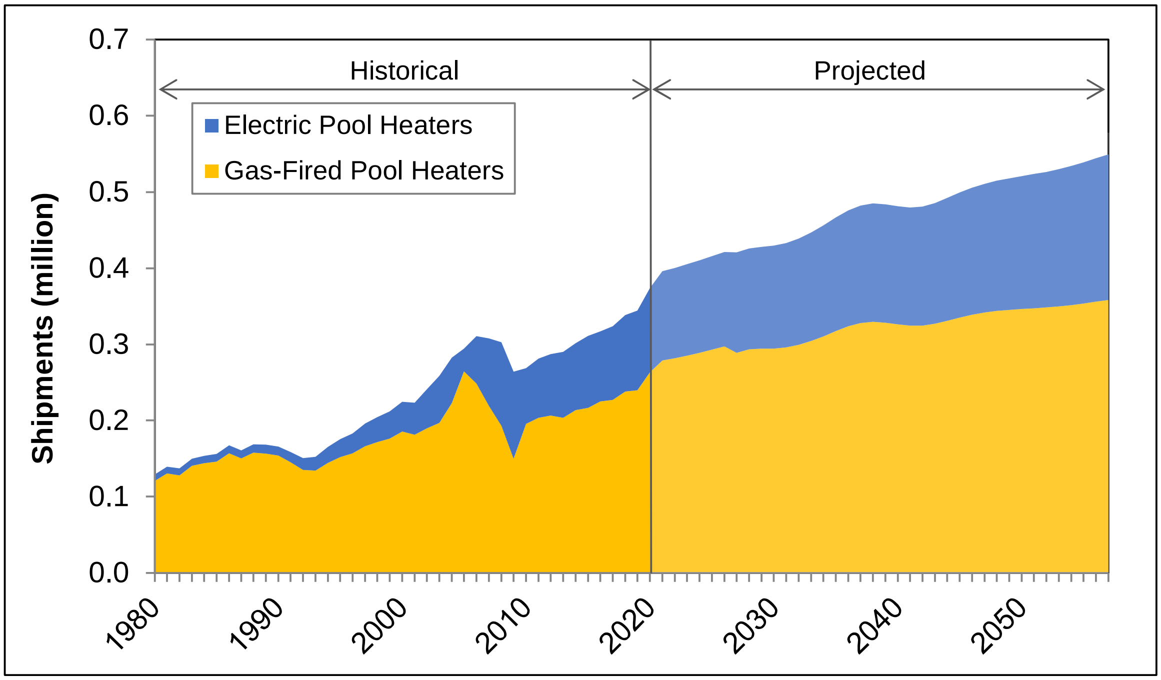

Figure 9.6.3 Historical (1980-2019) and Projected (2020-2057) Shipments of Electric and Gas-Fired Pool Heaters

9.6.2 Shipments Impacts Due to Standards

Figure 9.6.4 shows total projected shipments of electric pool heaters in the no-new-standards case and under each standards case. Figure 9.6.5 shows total projected shipments of gas-fired pool heaters in the no-new-standards case and under each standards case. Because the elasticity is modeled as a decline in pool heater shipments, the shipment projection decreases for each increase in efficiency level.

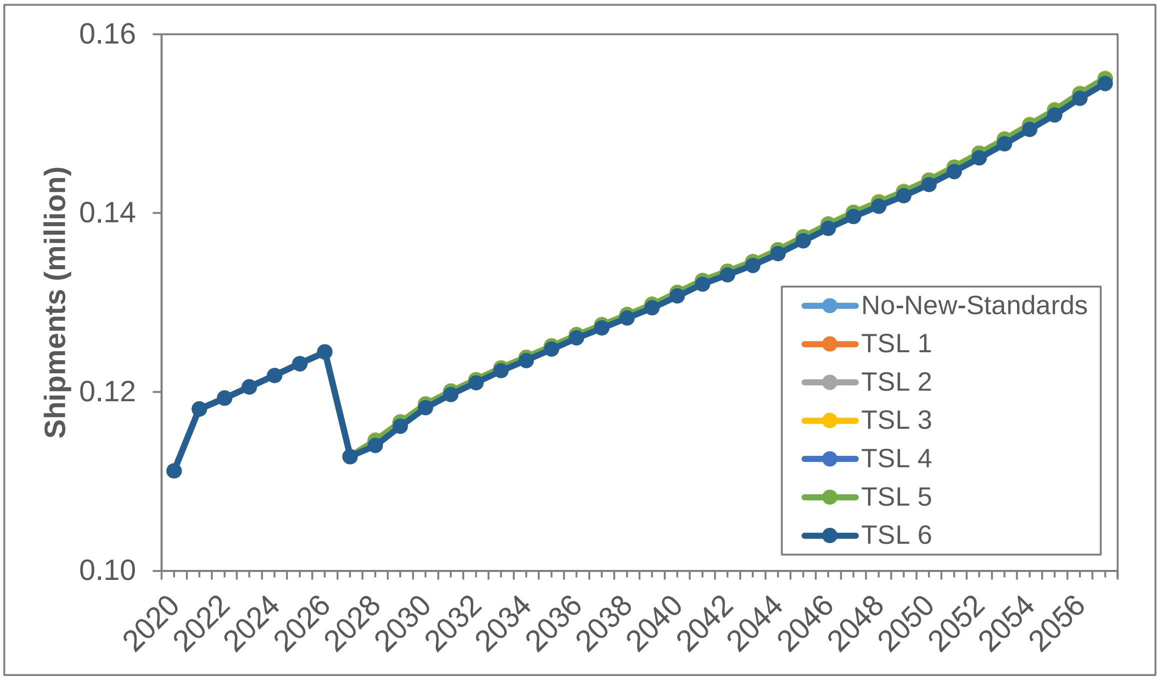

Figure 9.6.4 Total Projected Shipments of Electric Pool Heaters in the No-New-Standards Case and Each Standards Case

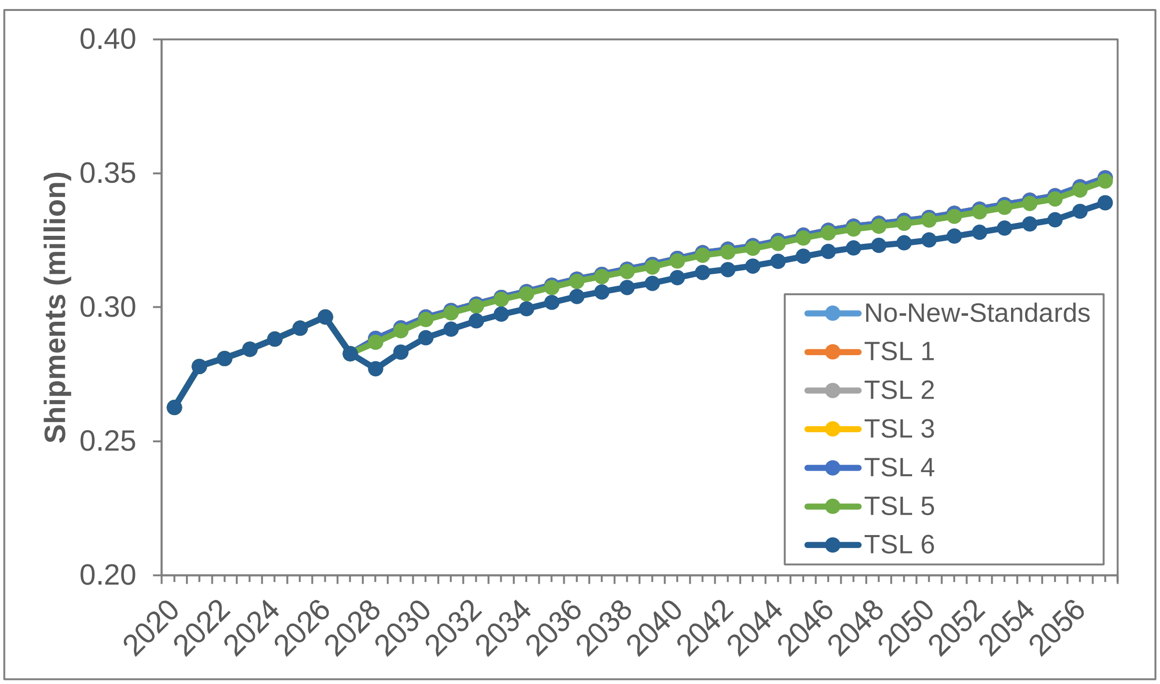

Figure 9.6.5 Total Projected Shipments of Gas-Fired Pool Heaters in the No-New-Standards Case and Each Standards Case

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CHAPTER 10. NATIONAL IMPACT ANALYSES

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CHAPTER 10. NATIONAL IMPACT ANALYSES

10.1 INTRODUCTION

This chapter describes the methods the U.S. Department of Energy (DOE) used to conduct a national impact analysis (NIA) of potential energy efficiency standard levels for electric pool heaters (EPHs) and gas-fired pool heaters (GPHs), and the results of the analysis. For each potential standard level, DOE evaluated the following impacts: (1) national energy savings (NES), (2) monetary value of the energy savings for consumers of pool heaters,[a] (3) increased total installed costs, and (4) the net present value (NPV), which is the difference between the savings in operating costs and the increase in total installed costs.

DOE determined the NES and NPV for all the trial standard levels (TSLs) considered for EPHs and GPHs. DOE performed all calculations using a Microsoft Excel spreadsheet model, which is accessible on the Internet at www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44. The spreadsheet combines the calculations for determining the NES and NPV for each considered TSL with input from the appropriate shipments model. Details and instructions for using the NIA model are provided in appendix 10A of this technical support document (TSD).

The NIA calculation starts with the shipments model. Chapter 9 of this TSD provides a detailed description of the shipments model that DOE used to project future purchases of EPHs and GPHs, and how standards might affect the level of shipments.

The analysis is described more fully in subsequent sections. The descriptions include overviews of how DOE performed each model's calculations and summaries of the major inputs. Table 10.1.1 summarizes inputs to the NIA model.

[a] For pool heaters installed in commercial applications, the consumer is the business or other entity that pays for the equipment (directly or indirectly) and its energy costs.

Table 10.1.1 Inputs to Calculating National Energy Savings and Net Present Value

Input	Data Description
Shipments	Annual shipments from shipments model (see chapter 9).
Compliance date of standard	2028.
Analysis period	For products shipped between 2028 through 2057.
Energy efficiency distributions in no-new-standards case	Based on historical data and on current consumer pool heater model availability by efficiency level (see chapter 8 and appendix 8H). DOE estimated growth in shipment-weighted efficiency by assuming a decrease overtime of the market share of baseline (EL 0) EPHs and GPHs.
Energy efficiency distributions in standards case	Roll-up in the compliance year and then DOE estimated growth in shipment-weighted efficiency in all the standards cases, except max-tech.
Total installed cost per unit	Shipments-weighted total per-unit average annual installed cost varies by efficiency level (see chapter 8). DOE incorporated future product price trends based on historical data.
Annual energy consumption per unit	Annual weighted-average values are a function of shipments-weighted unit energy consumption (UEC) at each efficiency level (see chapter 7).
Rebound effect	Applied a rebound effect value dependent on application and sector (see section 10.3.4).
Energy prices	2028 base year energy prices based on baseline average and marginal energy prices in 2021 from Energy Information Administration (EIA) historical data and price trends from EIA's Annual Energy Outlook 2022 with Projections to 2050 (AEO 2022)[1] (see chapter 8 and appendix 8D).
Energy Price Trends	*AEO 2022* projections to 2050 and extrapolation thereafter.
Annual energy cost per unit	Annual weighted-average values as a function of shipments-weighted annual energy consumption per unit and energy prices.
Repair and maintenance cost per unit	Annual values do not change with efficiency level (see chapter 8 and appendix 8E).
Energy site-to-primary conversion factors	A time-series conversion factor that includes losses due to electricity generation, transmission, and distribution.
Full-fuel-cycle multiplier	A time-series conversion factor based on AEO 2022 that includes energy consumed in extracting, processing, and transporting or distributing primary fuels (see appendix 10B).
Discount rate	Three and seven percent.
Present year	Future expenses are discounted to 2022.
Dollar year	DOE expressed all costs in 2021$.

10.1.1 Trial Standard Levels

DOE analyzed the benefits and burdens of six TSLs for consumer pool heaters. These TSLs were developed by combining specific efficiency levels for each of the product classes analyzed by DOE. Table 10.1.2 presents the TSLs and the corresponding efficiency levels at the representative capacity (110 kBtu/h output capacity for EPHs and 250 kBtu/h input capacity for GPHs) that DOE has identified for potential amended energy conservation standards for consumer pool heaters. TSL 6 represents the max-tech energy efficiency for all product classes (*i.e.*, efficiency level 5 for EPHs and efficiency level 3 for GPHs). TSL 5 corresponds to efficiency level 4 for EPHs and efficiency level 2 for GPHs, which represents the highest efficiency level that yields the maximum NPV at 7 percent discount rate and for which the percentage of LCC winners is higher than the percentage of LCC losers for each product class. TSL 4 corresponds to efficiency level 4 for EPHs and efficiency level 1 for GPHs. TSL 3 corresponds to efficiency level 3 for EPHs and efficiency level 1 for GPHs. TSL 2 corresponds to the efficiency level 2 for EPHs and efficiency level 1 for GPHs. TSL 1 corresponds to efficiency level 1 for EPHs and efficiency level 1.

Table 10.1.2 Trial Standard Levels for Proposed Consumer Pool Heater Standards

Product Class	Trial Standard Level					
	1	**2**	**3**	**4**	**5**	**6**
	Representative TE_I (%)					
Electric Pool Heaters	387	483	534	551	551	595
Gas-fired Pool Heaters	81.3	81.3	81.3	81.3	83.3	94.8
	Efficiency Level					
Electric Pool Heaters	1	2	3	4	4	5
Gas-fired Pool Heaters	1	1	1	1	2	3

10.2 PROJECTED ENERGY EFFICIENCY TREND

The trend in forecasted energy efficiency is a key factor in estimating NES and NPV for the no-new-standards case and each potential standards case. For calculating the NES, per-unit average annual energy consumption is a direct function of product energy efficiency. For the NPV, both the per-unit total installed cost and the per-unit annual operating cost are dependent on product energy efficiency.

DOE used as a starting point the shipments-weighted energy efficiency distribution for 2028 (the assumed date of compliance with a new standard). To represent the distribution of product energy efficiencies in 2028, DOE used the same market shares as used in the no-new-standards case for the life-cycle cost analysis (described in chapter 8 of this TSD).

To project efficiencies for the no-new-standards case, DOE assumed an annual decreasing constant growth rate of negative 2 percent for the minimum efficiency levels (EL 0) for both electric and gas-fired pool heaters. This resulted in a market share for EL 0 of 8 percent in 2028 and 5 percent in 2057 for electric pool heaters and 4 percent in 2028 and 2 percent in 2057 for gas-fired pool heaters.

To determine the standards-case efficiencies, DOE assumed a “roll-up” scenario to establish the shipment-weighted efficiency for the year that standards are assumed to take effect (2028). DOE assumed that product efficiencies in the no-new-standard case that did not meet the standard under consideration would “roll up” to meet the new standard level. DOE also assumed that all product efficiencies in the no-new-standard case that exceeded the standard would not be affected. Taking this efficiency distribution as a starting point, DOE projected standards-case efficiencies based on assumptions regarding future efficiency improvements similar to that of the no-new-standards case.

Table 10.2.1 presents the efficiency distributions in 2028 for the no-new-standards case and for each TSL for consumer pool heaters used in residential applications. For the no-new-standards case efficiency distributions disaggregated by region and consumer pool heater market type, see appendix 8H. Figure 10.2.1 and Figure 10.2.2 shows the assumed no-new-standards case market shares of electric pool heaters and gas-fired pool heaters at each EL throughout the analysis period (2028-2057).

Table 10.2.1 Efficiency Distributions for Consumer Pool Heaters in 2028, percent

Product Class	EL	No-New-Standards Case	Trial Standard Level (TSL)					
			1	2	3	4	5	6
Electric Pool Heaters	0	8.1						
	1	10.5	18.6					
	2	59.6	59.6	78.2				
	3	9.4	9.4	9.4	87.6	87.6		
	4	9.4	9.4	9.4	9.4	9.4	97.0	
	5	3.0	3.0	3.0	3.0	3.0	3.0	100
Gas-fired Pool Heaters	0	3.6						
	1	46.4	50.0	50.0	50.0	50.0		
	2	41.4	41.4	41.4	41.4	41.4	91.3	
	3	8.7	8.7	8.7	8.7	8.7	8.7	100

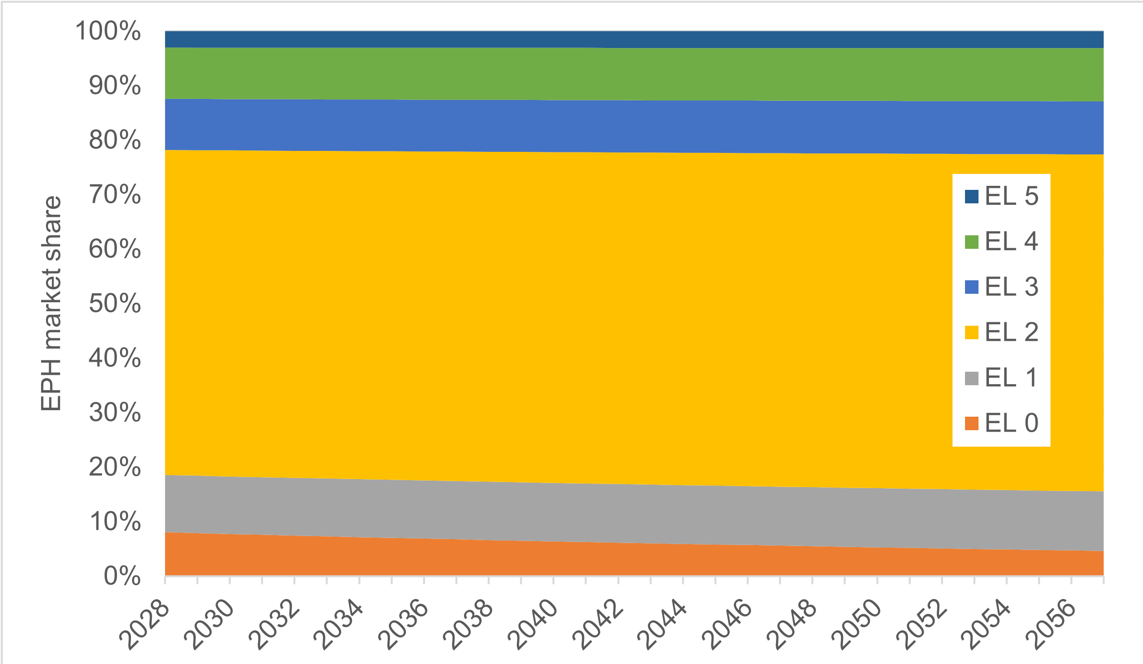

Figure 10.2.1 Projection of No-New-Standards Case Efficiency Distribution for Electric Pool Heaters, 2028-2057

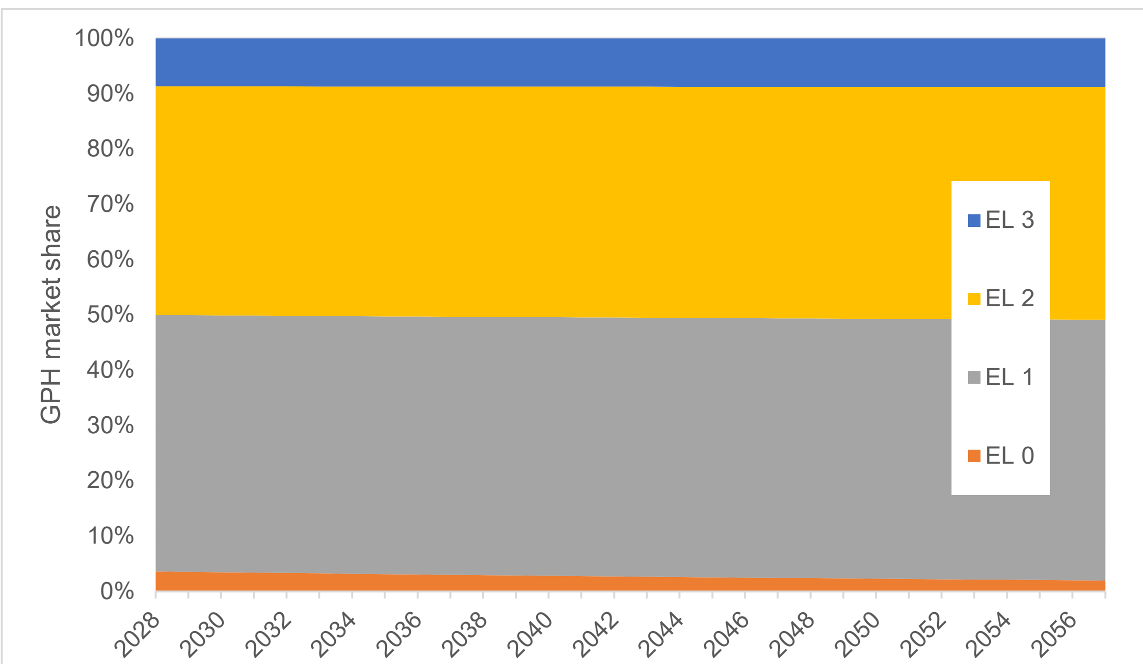

Figure 10.2.2 Projection of No-New-Standards Case Efficiency Distribution for Gas-Fired Pool Heaters, 2028-2057

10.3 NATIONAL ENERGY SAVINGS

DOE calculated the NES associated with the difference between the no-new-standards case and each standards case for EPHs and GPHs. DOE's analysis considered products shipped in the 30-year period beginning in the compliance year—in this case, 2028. DOE calculated cumulative energy savings throughout the analysis period, which ends when all of the products shipped in 2057 are retired from the stock.

10.3.1 Definition

DOE reported the cumulative national energy savings (NES) in terms of three energy measures: site, primary, and full-fuel-cycle (FFC). [b] DOE calculated cumulative NES for each energy measures (denoted by *e*, below) as the sum of annual NES for a given year (denoted by *y*; NES_y) throughout the analysis period, represented by the following equation:

$$NES^{(e)} = \sum_{y} NES_y^{(e)}$$

Eq. 10.1

Where:

NES = cumulative national energy savings (quads),
NES_y = national annual energy savings (quads),
y = year in the projection, and
e = energy measurement type (site, primary, or FFC).

DOE calculated annual NES for each energy measures and for a given year as the difference between the national annual energy consumption (AEC) projections: the no-new-standards case scenario (AEC_{NNS}) and each standards case scenario (AEC_{STD}) corresponding to one of the TSLs. This is represented by the following equation:

$$NES_y^{(e)} = \left(AEC_{NNS,y}^{(e)} - AEC_{STD,y}^{(e)}\right) \times REF_y$$

Eq. 10.2

Where:

NES_y = national annual energy savings projections for a standards case scenario in quadrillion British thermal units (quads),
$AEC_{NNS.y}$ = national annual energy consumption projections for the no-new-standards case scenario (quads),
$AEC_{STD,y}$ = national annual energy consumption projections for the standards case scenario (quads),

---

[b] Site energy consumption is the energy consumed by the pool heater at the installation location. Primary energy consumption for electricity (power plant consumption) accounts for losses associated with the generation, transmission, and distribution of electricity. For both natural gas and propane, site and primary energy consumption are the same. The full-fuel-cycle energy consumption adds to the primary energy consumption the energy consumed "upstream" of the site in extracting, processing, and transporting or distributing primary fuels.

REF = rebound effect factor in year y,
y = year in the projection,
e = energy measurement type (site, primary, or FFC),
f = energy source (electricity, natural gas, or propone),
c = conversion factor by fuel type for converting site energy consumption to the primary and FFC energy consumption measurements (for site energy consumption, $c = 1$),
NNS = designates the quantity corresponding to the no-new-standards case, and
STD = designates the quantity corresponding to the standards case corresponding to one of the TSLs.

DOE calculated the national annual energy consumption for each energy measurement type by multiplying the national annual site energy consumption (*i.e.*, the energy consumed at the household or establishment; *ASEC*) for each energy source type (denote by f, below) by the conversion factor for each energy measurement type which varies by year, energy source type ($c_{y,f}$), as follows:

$$AEC_y^{(e)} = \sum_f ASEC_{y,f} \times c_{y,f}^{(e)}$$

Eq. 10.3

Where:

AEC_y = national annual energy consumption projections for the no-new-standards case scenario or standards case scenario (quads),
$ASEC_{y,f}$ = national annual site energy consumption projections for the no-new-standards case scenario or standards case scenario for each energy source type (quads),
y = year in the projection,
e = energy measurement type (site, primary, or FFC),
f = energy source type (electricity, natural gas, or propone), and
$c_{y,f}$ = conversion factor by energy source type for converting site energy consumption to the primary and FFC energy consumption measurements (for site energy consumption, $c = 1$),

DOE calculated the national annual site energy consumption by multiplying the number or stock of the product (STOCK; by vintage, denoted by *V*) by its unit energy consumption (UEC; also by vintage), as follows:

$$ASEC_{y,f} = \sum_V STOCK_V \times UEC_{V,y,f}$$

Eq. 10.4

Where:

$ASEC_{y,f}$ = annual national site energy consumption in quads, summed over vintages of the product stock, $STOCK_V$;
$STOCK_V$ = stock of EPHs or GPHs (millions of units) of vintage V that survive in the year for which DOE calculates the AEC

$UEC_{V,y,f}$ = annual energy consumption per unit of EPHs or GPHs per year, which accounts for differences in UEC from year to year,
V = year in which the product was purchased as a new unit,
y = year in the forecast, and
f = energy source type (electricity, natural gas, or propone).

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9 of this TSD, DOE projected product shipments under the no-new-standards case and standards cases. To avoid including savings attributable to shipments displaced (units not purchased) because of standards, DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the AEC for the no-new-standards case.

10.3.2 National Energy Savings Inputs

The inputs for calculating national energy savings were:

- annual energy consumption per unit ($UEC_{y,f}$),
- shipments and product stock ($STOCK_V$),
- conversion factors for site-to-primary ($c_{y,f}$),
- full-fuel-cycle (FFC) ($c_{y,f}$), and
- rebound effect factor (REF_y).

10.3.2.1 Annual Energy Consumption per Unit

DOE developed per-unit annual energy consumption as a function of product energy efficiency for EPHs and GPHs (see chapter 7 of this TSD). DOE used the shipments-weighted energy efficiencies for the no-new-standards case and standards cases, along with the estimates of annual energy use by efficiency level, to estimate the shipments-weighted annual average per-unit energy use under the no-new-standards and standards cases.

For each product class, DOE presented the per-unit annual energy consumption as a function of product efficiency in chapter 7, Energy Use Analysis. Because the per-unit annual energy consumption is directly dependent on efficiency, DOE used the shipments-weighted energy efficiency of the no-new-standards and standards cases presented in section 10.2, along with the annual energy use data presented in chapters 7 and 8, to estimate the shipment-weighted average annual per-unit energy consumption (UEC) under the no-new-standards and standards cases.

Table 10.3.1 presents the no-new-standards case and standards case shipment-weighted annual UECs for consumer pool heaters in 2028. The values are a weighted average of residential and commercial pool heater users.[c] The table shows the energy use of consumer pool heaters associated with higher efficiencies. The values after 2028 change according to the

[c] Based on the shipment analysis, DOE estimated that 6 percent of electric pool heaters and 13 percent of gas-fired pool heaters will be shipped to commercial buildings in 2028 (see chapter 9).

projected efficiency trends in each case. Table 10.3.2 shows the resulting differential in UEC between the standards cases and the no-new-standards case.

Table 10.3.1 Average Annual Consumer Pool Heater Unit Energy Consumption (UEC) for the No-New-Standards and Standards Cases in 2028

Product Class (Energy Source)	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters							
Electricity Use (*kWh/yr*)	4,365	3,447	3,305	3,053	2,954	2,954	2,845
Gas-fired Pool Heaters							
Fuel Use (*MMBtu/yr*)	179.3	177.3	177.3	177.3	177.3	175.6	159.4
Electricity Use (*kWh/yr*)	94.3	94.5	94.5	94.5	94.5	101.4	78.8

Table 10.3.2 Average Annual Consumer Pool Heater UEC Savings Between Standards Cases in Comparison to the No-New-Standards Case in 2028

Product Class (Energy Source)	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters							
Electricity Use (*kWh/yr*)	-	918	1,059	1,311	1,410	1,410	1,519
Gas-fired Pool Heaters							
Fuel Use (*MMBtu/yr*)	-	1.9	1.9	1.9	1.9	3.7	19.8
Electricity Use (*kWh/yr*)	-	(0.2)	(0.2)	(0.2)	(0.2)	(7.0)	15.5

Note: Parentheses indicate negative (−) values.

Note that the results in Table 10.3.1 are not adjusted for the impact of the rebound effect discussed in section 10.3.4. For this NIA, DOE applied a rebound effect parameter that reduces the estimated national energy savings. In addition, DOE considered the effects of changes in climate on consumer pool heater energy use. At this time it is unclear the impact of increasing warmer weather (as forecast by decreasing heating degree days (HDD) and increasing cooling degree days (CDD) in AEO 2022) will have on consumer pool heater energy use, since a warmer temperatures in the summer will tend to decrease consumer pool heater load, which could be offset by increasing pool season due to warmer temperatures in the colder months.

10.3.2.2 Shipments and Product Stock

As described in chapter 9, DOE forecasted shipments of EPHs and GPHs under the no-new-standard case and all standards cases. Because the increased total installed cost of more efficient products may cause some customers to forego purchasing the product, shipments forecasted under the standards cases may be lower than under the no-new-standard case. DOE believes it would be inappropriate to count energy savings that result from a decline in shipments because of standards. Therefore, each time a standards case was compared with the no-new-standard case, DOE used shipments associated with that particular standards case. As a result, all of the calculated energy savings are attributable to higher energy efficiency in the standards case.

The product stock in a given year (*$STOCK_V$*) is the number of products shipped from earlier years that survive in that year. The shipments model, which feeds into the NIA, tracks the number of units shipped each year. DOE assumed that products would have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is called the survival function. Chapter 9 of this TSD provides additional details on the survival function that DOE used for EPHs and GPHs.

10.3.2.3 Site-to-Power Plant Energy Use Factor

As shown in 10.3.1, in determining national AEC, DOE first calculated AEC at the site ($ASEC_{y,f}$), then applied a conversion factor to calculate primary energy consumption. The site-to-primary energy conversion factor is a multiplicative factor used to convert site energy consumption into primary, or source, energy consumption, expressed in quadrillion Btus (quads). For natural gas and propane the site-to-primary energy conversion factors is 1.

For electricity consumption, DOE calculated primary energy savings (power plant consumption) from site electricity savings by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. For electricity from the grid, primary energy consumption is equal to the heat content of the fuels used to generate that electricity.[d] DOE used annual average site-to-power plant conversion factors based on the version of the National Energy Modeling System (NEMS)[e] that corresponds to the AEO 2022. The factors are marginal values, which represent the response of the national power system to incremental changes in consumption. The conversion factors change over time in response to projected changes in generation sources (the types of power plants projected to provide electricity). Appendix 10B describes how DOE derived these factors.

Figure 10.3.1 shows the site-to-power plant energy conversion factors for EPHs and GPHs from 2028 to 2050. For years after 2050 (the last year in the AEO), DOE maintained the 2050 value. The conversion factors were generated from NEMS based on the estimated electricity load for "other uses".

[d] For electricity sources such as nuclear energy and renewable energy, the primary energy was calculated using the convention used by EIA (see appendix 10B).

[e] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation.[2] EIA approves use of the name NEMS to describe only an official version of the model with no modification to code or data.

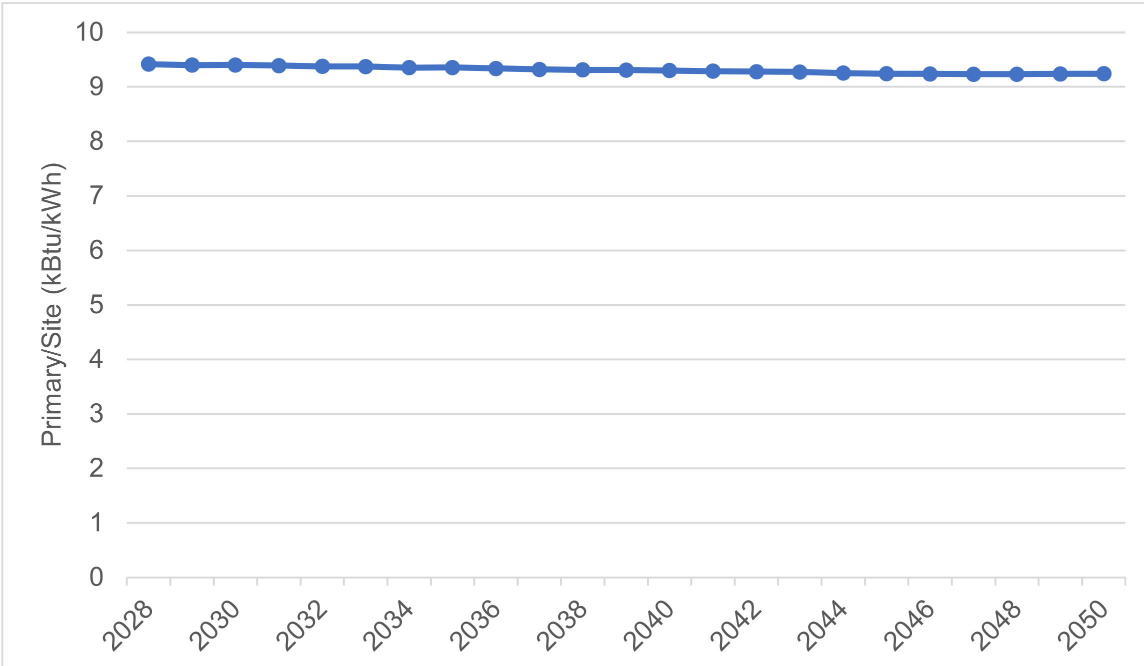

Figure 10.3.1 Primary to Site Energy Use Factor for Consumer Pool Heater Electricity Use, 2028-2050

10.3.3 Full-Fuel-Cycle Multipliers

As shown in section 10.3.1, in determining national AEC, DOE first calculated AEC at the site (*ASEC*), then applied a conversion factor to calculate FFC energy consumption. DOE used an FFC multiplier to account for the energy consumed in extracting, processing, and transporting or distributing primary fuels, which are referred to as upstream activities. DOE developed FFC multipliers using the data and projections generated for AEO 2022. AEO 2022 provides extensive information about the energy system, including projections of future oil, natural gas, and coal supplies; energy use for oil and gas field and refinery operations; and fuel consumption and emissions related to electric power production. The information can be used to define a set of parameters that represent the energy intensity of energy production. For natural gas, the FFC multiplier includes leakage in upstream activities.

The method used to calculate FFC energy multipliers is described in appendix 10B of this TSD. For electricity, the multipliers were applied to primary energy consumption. Table 10.3.3 shows the FFC energy multipliers for selected years.

Table 10.3.3 Full Fuel Cycle Energy Multipliers (Based on AEO 2022)

	2025	2030	2035	2040	2045	2050
Electricity	1.042	1.039	1.038	1.037	1.038	1.037
Natural Gas	1.099	1.098	1.098	1.098	1.100	1.099

10.3.4 Rebound Effect

A rebound effect may follow an energy conservation standard, in that consumers may increase usage of a product because it costs less to operate than previous units.[f] A rebound effect reduces the energy savings attributable to a standard.[3,4,5,6] Where appropriate, DOE accounted for the direct rebound effect for a conservative estimate of the NES from potential standards. For consumer pool heaters, DOE applied a rebound effect of 10 percent for residential applications based on the rebound effect value used for gas pool heaters in the 2010 Final Rule for Heating Products[7] and 2015 Notice of Data Availability (NODA) for EPHs[8] and zero percent for commercial applications. Although a lower value might be warranted, DOE preferred to be conservative and not risk understating the rebound effect. A rebound effect of 10 percent means that 10 percent of the estimated energy savings do not materialize because of increased use of the product (see chapter 8 for further discussion).

10.4 NET PRESENT VALUE OF CONSUMER BENEFITS

DOE calculated the NPV of consumer benefits associated with the difference between the no-new-standards case and each standards case for EPHs and GPHs. The inputs for determining the NPV of the total costs and benefits experienced by consumers are (1) total annual installed cost, (2) total annual operating costs (energy costs and repair and maintenance costs), and (3) a discount factor to calculate the present value of costs and savings. DOE's analysis considers products shipped in the 30-year period beginning in the compliance year—in this case, 2028. DOE calculated NPV throughout the analysis period, which ends when all of the products shipped in 2057 are retired from the stock.

10.4.1 Definition

The NPV is the value in the present of a time-series of costs and savings. The NPV is described by the equation:

$$NPV = PVS - PVC$$

Where:

PVS = present value of operating cost savings,[g] and
PVC = present value of increased total installed costs (purchase price and any installation costs).

DOE determined the PVS and PVC according to the following expressions:

[f] This response is referred to as a direct rebound effect. It is difficult to account for economy-wide indirect rebound effects, which reflect how consumers spend the money saved by energy conservation.
[g] The operating cost includes energy, repair, and maintenance costs.

$$PVS = \sum_y OCS_y \times DF_y$$

$$PVC = \sum_y TIC_y \times DF_y$$

Where:

OCS = total annual-savings in operating costs summed over vintages of the stock,
DF = discount factor in each year,
TIC = total annual increases in installed cost summed over vintages of the stock, and
y = year in the forecast.

DOE calculated the total annual consumer savings in operating costs by multiplying the number or stock of the product (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increases in consumer product price by multiplying the number or shipments of the product (by vintage) by its per-unit increase in consumer cost (also by vintage). Total annual operating cost savings and total annual product cost increases are calculated by the following equations.

$$OCS_y = \sum_V STOCK_{V,y} \times UOCS_{V,y}$$

$$TIC_y = SHIP_y \times UTIC_y$$

Where:

OCS_y = total annual savings in operating cost each year summed over vintages of the product stock, $STOCK_V$,
$STOCK_{V,y}$ = stock of products of vintage *V* that survive in the year for which DOE calculated annual energy consumption,
$UOCS_{V,y}$ = annual operating cost savings per unit of vintage *V*,
V = year in which the product was purchased as a new unit,
y = year in the forecast,
TIC_y = total increase in installed product cost in year *y*,
$SHIP_y$ = shipments of the product in year *y*,
$UTIC_y$ = annual per-unit increase in installed product cost in year *y*.

DOE determined the total increased product cost for each year from 2028 to 2057. The increase in total annual installed cost for a product under any given standards case is the product of the increase in total installed cost per unit attributable to the standard and the number of units of each vintage. This method accounts for differences in total installed cost from year to year.

DOE determined the present value of operating cost savings for each year from 2028 to the year when all units purchased in 2057 are estimated to retire. The savings in total annual operating cost for any given candidate standards level is the product of the annual per-unit savings in operating cost attributable to the standard and the number of units of each vintage. This method accounts for the year-to-year differences in annual operating cost savings.

DOE calculated installed cost and operating cost savings as the difference between a standards case and a no-new-standards case. As with the calculation of NES, DOE did not use no-new-standards case shipments to calculate total annual installed costs and operating cost savings. To avoid including savings attributable to shipments displaced by consumers deciding not to buy higher-cost products, DOE used the standards-case projection of shipments and, in turn, the standards-case stock, to calculate these quantities.

DOE developed a discount factor from the national discount rate and the number of years between the "present" (year to which the sum is being discounted) and the year in which the costs and savings occur.

10.4.2 Net Present Value Inputs

The inputs to the calculation of NPV were:

- Total installed cost per unit ($UTIC_y$),
- annual operating cost savings per unit ($UOCS_{V,y}$),
- shipments ($SHIP_y$) and product stock ($STOCK_V$),
- discount factor (DF_y), and
- rebound effect factor.

10.4.3 Total Installed Cost Per Unit

The per-unit total installed cost is a function of product energy efficiency. Therefore, DOE used the shipments-weighted efficiencies of the no-new-standards case and standards cases described in section 10.2, in combination with the total installed costs developed in chapter 8, to estimate the shipments-weighted average annual per-unit total installed cost under the various cases. Table 10.4.1 shows the shipment-weighted average total installed cost for consumer pool heaters in the residential and commercial sector[h] in 2028 based on the efficiencies that correspond to the no-new-standards case and each TSL. Table 10.4.2 shows the resulting differential in shipments-weighted average annual per-unit total installed cost between the standards cases and the no-new-standards case.

[h] Based on the shipment analysis, DOE estimated that 6 percent of electric pool heaters and 13 percent of gas-fired pool heaters will be shipped to commercial buildings in 2028 (see chapter 9).

Table 10.4.1 Average Total Installed Cost of Consumer Pool Heaters in 2028 for the No-New-Standards and Standards Cases (2021$)

Product Class	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters	4,191	4,252	4,268	4,346	4,474	4,474	4,662
Gas-fired Pool Heaters	3,675	3,675	3,675	3,675	3,675	3,800	4,652

Table 10.4.2 Average Total Installed Cost of Consumer Pool Heaters in 2028 Differential between the Standards Cases and the No-New-Standards Case (2021$)

Product Class	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters	-	61	77	156	283	283	471
Gas-fired Pool Heaters	-	0	0	0	0	125	977

As discussed in chapter 8 of this TSD, DOE developed a price trend based on an experience curve. DOE used the price trend to project the prices of consumer pool heaters sold in each year of the forecast period (2028–2057). The resulting annual price decline rates are 0.16%, 0.37%, and 0.33% for electric resistance pool heaters (EL 0 for EPHs), heat pump pool heaters (EL 1 to EL 5 for EPHs), and gas-fired pool heaters, respectively.

The increase in total annual installed cost for any given EL is the product of the total installed cost increase per unit under that standard and the number of units of each vintage. This approach accounts for differences in total installed cost from year to year.

10.4.4 Annual Operating Cost Savings Per Unit

Per-unit annual operating costs encompass the annual costs for energy, repair, and maintenance. DOE determined the savings in per-unit annual energy cost by multiplying the savings in per-unit annual energy consumption by the appropriate energy price, and any associated costs or savings for repair and maintenance. DOE considered operating costs separately for residential and commercial users.

Estimates of the per-unit annual energy consumption for the no-new-standards case and each standards case were presented in section 10.3.2.1. DOE projected the per-unit annual energy consumption for the no-new-standards case for all product classes by applying a growth trend in efficiency. As described in chapter 8 of this TSD, to estimate energy prices in future years, DOE multiplied the recent energy prices by a projection of annual national-average residential and commercial energy prices based on EIA's AEO 2022 reference case scenario.

DOE described the total per-unit repair and maintenance costs for each product class as a function of product efficiency in chapter 8. Because the per-unit repair and maintenance costs depend directly on efficiency, DOE used the efficiencies for the no-new-standards and standards cases presented in section 10.2, combined with the repair and maintenance costs presented in chapter 8, to estimate the per-unit average repair and maintenance costs under the no-new-standards and standards cases.

Table 10.4.3 shows the shipments-weighted average annual operating cost of consumer pool heaters in 2028 for the no-new-standards and standards cases. The operating costs change over time, depending on change in annual energy use and energy prices as well as repair and maintenance costs. Table 10.4.4 shows the resulting shipments-weighted average annual operating cost savings of consumer pool heaters in 2028 between the standards cases and the no-new-standards case.

Table 10.4.3 Average Annual Operating Cost of Consumer Pool Heaters in 2028 for the No-New-Standards and Standards Cases (2021$)

Product Class	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters	668	548	530	497	484	484	469
Gas-fired Pool Heaters	2,051	2,030	2,030	2,030	2,030	2,013	1,845

Table 10.4.4 Average Annual Operating Cost Savings of Consumer Pool Heaters in 2028 Between the Standards Cases and the No-New-Standards (2021$)

Product Class	No-New-Standards Case	Trial Standard Levels					
		1	2	3	4	5	6
Electric Pool Heaters	-	120	138	171	184	184	199
Gas-fired Pool Heaters	-	21	21	21	21	38	206

10.4.5 Product Stock

As described in chapter 9, DOE forecasted shipments of EPHs and GPHs under the no-new-standard case and all standards cases. Because the increased total installed cost of more efficient products may cause some customers to forego purchasing the product, shipments forecasted under the standards cases may be lower than under the no-new-standard case. DOE believes it would be inappropriate to count energy savings that result from a decline in shipments because of standards. Therefore, each time a standards case was compared with the no-new-standard case, DOE used shipments associated with that particular standards case. As a result, all of the calculated energy savings are attributable to higher energy efficiency in the standards case.

The product stock in a given year ($STOCK_V$) is the number of products shipped from earlier years that survive in that year. The shipments model, which feeds into the NIA, tracks the number of units shipped each year. DOE assumed that products would have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is called the survival function. Chapter 9 of this TSD provides additional details on the survival function that DOE used for EPHs and GPHs.

The stock of product in any given year depends on annual shipments and the lifetime of a given product class. The NIA model keeps track of the number of units shipped each year. The lifetime of a unit determines how many units shipped in previous years survive in the given year. DOE assumed that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is termed the survival function.

Refer to the specific section for each product class in appendix 8F for further details on the survival functions that DOE used in its analysis.

10.4.6 Rebound Effect

As previously discussed, a rebound effect may follow an energy conservation standard, in that consumers may increase usage of a product because it costs less to operate than previous models. The increase in energy consumption associated with the rebound effect represents increased value to consumers (*e.g.*, a more comfortable swimming pool or spa temperature). The net effect is the sum of (1) the change in the cost of owning a product (that is, national consumer expenditures for total installed and operating costs) and (2) the increased value of the enhanced service from the product. In considering the consumer welfare gained due to the direct rebound effect, DOE accounted for change in consumer surplus attributed to additional heating from the purchase of a more efficient unit. Overall consumer surplus is generally understood to be enhanced from rebound. The net consumer impact of the rebound effect is included in the calculation of operating cost savings in the consumer NPV results. See appendix 10G of this final rule TSD for details on DOE's treatment of the monetary valuation of the rebound effect.

10.4.7 Discount Factor

DOE multiplied monetary values in future years by a discount factor to determine present values. The discount factor (DF) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_P)}}$$

Where:
r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

DOE used both a 3-percent and a 7-percent real discount rate when estimating national impacts. Those discount rates were applied to product prices of consumer pool heaters in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on developing regulatory analyses (OMB Circular A-4, September 17, 2003, and section E., "Identifying and Measuring Benefits and Costs," therein).[9] DOE defined the present year as 2028.

10.4.8 Present Value of Increased Installed Cost and Savings

The present value of increased installed costs is the annual increase in installed cost for each year (*i.e.*, the difference between the standards case and no-new-standards), discounted to the present and summed over the forecast period (2028–2057). The increase in total installed cost refers to both product and installation costs associated with the higher energy efficiency of products purchased under a standards case compared to the no-new-standards case.[i] DOE calculated annual increases in installed cost as the difference in total cost of new products installed each year, multiplied by the shipments in the standards case.

The present value of operating cost savings is the annual savings in operating cost (the difference between the no-new-standards case and a standards case), discounted to the present and summed over the period that begins with the expected compliance date of potential standards and ends when the last installed unit is retired from service. Savings represent decreases in operating costs associated with the higher energy efficiency of products purchased in a standards case compared to the no-new-standards case. Total annual operating cost savings are the savings per unit multiplied by the number of units of each vintage that survive in a particular year. Because a product consumes energy throughout its lifetime, the energy consumption for units installed in a given year includes energy consumed until the unit is retired from service.

10.5 RESULTS

This section presents the NES and NPV results for the considered TSLs for consumer pool heaters.

10.5.1 National Energy Savings

This section provides NES results that DOE calculated for each TSL analyzed for consumer pool heaters. To estimate the NES attributable to potential new or amended standards for consumer pool heaters, DOE compared their energy consumption under the no-new-standards case to their anticipated energy consumption under each TSL. NES results are shown as savings in site, primary, and FFC energy. Because DOE based the inputs to the NIA model on weighted-average values, results are discrete point values, rather than a distribution of values as produced by the life-cycle cost and payback period analysis. Table 10.5.1 presents DOE's projections of the national energy savings for each TSL considered for consumer pool heaters. The savings are measured over the entire lifetime of products purchased in the 30-year period that begins in the year of anticipated compliance with amended standards (2028–2057).

[i] For the NIA, DOE excludes sales tax from the product cost, because sales tax is essentially a transfer and therefore is more appropriate to include when estimating consumer benefits.

Table 10.5.1 Cumulative National Energy Savings for Consumer Pool Heaters; 30 Years of Shipments (2028–2057)

Energy Savings	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		*quads**					
Site energy	Electric Pool Heaters	0.08	0.10	0.14	0.15	0.15	0.17
	Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.28	2.59
	Total	**0.10**	**0.12**	**0.16**	**0.17**	**0.43**	**2.76**
Primary energy	Electric Pool Heaters	0.22	0.28	0.38	0.41	0.41	0.46
	Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.27	2.60
	Total	**0.24**	**0.30**	**0.39**	**0.43**	**0.69**	**3.05**
FFC energy	Electric Pool Heaters	0.23	0.29	0.39	0.43	0.43	0.47
	Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.27	2.60
	Total	**0.25**	**0.31**	**0.41**	**0.45**	**0.70**	**3.07**

* quads = quadrillion British thermal units.
Note: numbers may not add to totals, due to rounding.

10.5.2 Net Present Value of Consumer Benefit

This section provides results of calculating the NPV of consumer benefits for each TSL considered for consumer pool heaters. DOE estimated the cumulative NPV of the total costs and savings for consumers that would result from the TSLs considered for consumer pool heaters. Results, which are cumulative, are shown as the discounted value of the net savings in dollar terms. In accordance with OMB's guidelines on regulatory analysis, DOE calculated NPV using both a 7-percent and a 3-percent real discount rate. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis. Table 10.5.2 shows the consumer NPV results with impacts counted over the lifetime of products purchased in 2028–2057.

Table 10.5.2 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters; 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.48	1.82	2.33	2.32	2.32	2.20
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.68	7.41
	Total	**1.60**	**1.93**	**2.45**	**2.44**	**3.00**	**9.60**
7 percent	Electric Pool Heaters	0.64	0.78	0.99	0.96	0.96	0.87
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.23	2.66
	Total	**0.70**	**0.84**	**1.04**	**1.01**	**1.18**	**3.53**

Note: Parentheses indicate negative values. Numbers may not add to totals, due to rounding.

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

The consumer subgroup analysis evaluates impacts on groups or customers who may be disproportionately affected by any national energy conservation standard. The U.S. Department of Energy (DOE) evaluated impacts on particular subgroups of consumers by analyzing the life-cycle cost (LCC) impacts and payback period (PBP) for those consumers from the considered energy efficiency levels. DOE determined the impact on consumer subgroups using the LCC spreadsheet models for pool heaters. Chapter 8 explains in detail the inputs to the models used in determining LCC impacts and PBPs.

DOE evaluated the impacts of the considered energy efficiency levels for pool heaters on households occupied solely by senior citizens (*i.e.*, senior-only households) and consumer pool heaters installed by small businesses.[a] The analysis used subsets of the consumer pool heater sample composed of households or buildings that meet the criteria for the subgroup. DOE used the LCC and PBP spreadsheet model to estimate the impacts of the considered efficiency levels on these subgroups.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroup.

11.2 SUBGROUPS DEFINITION

11.2.1 Senior-Only Households Development

Senior-only households have occupants who are all at least 65 years of age. Based on the Energy Information Administration's (EIA)'s 2009 Residential Energy Consumption Survey (RECS 2009),[1] senior-only households comprised 16.5 percent of the country's households. For this analysis, DOE used EIA's RECS 2015,[2] which does not include information about the age of all the occupants in the home (it only includes the age of the respondent of the survey). To identify all potential senior-only households in RECS 2015, DOE used information from RECS 2009 on households where the respondent is at least 65 years of age or older (See Table 11.2.1). DOE applied these fractions to sample weights in RECS 2015 of households where the respondent is at least 65 years of age and estimated that senior only households comprised 18.5 percent of the country's households. The increase in senior only households coincides with other survey data showing an increasing fraction of seniors in the country.

[a] DOE did not evaluate low-income consumer subgroup impacts for pool heaters because the sample size of the subgroups is too small for meaningful analysis.

Table 11.2.1 Fraction of Senior Only Households by Household Size When Respondent is at least 65 years or Older from RECS 2009 data

Household Size	Fraction of Senior Only Households
1	100.0%
2	70.2%
3	7.9%
4 or more	0.0%

11.2.2 Small Business Subsample development

DOE identified small businesses within EIA's 2012 Commercial Buildings Energy Consumption Survey (CBECS 2012)[3] database by using threshold levels for maximum number of employees within each building type (such as Real estate investment trust (REIT), Outpatient health care, Public assembly, Inpatient health care, and Lodging). DOE estimated the fraction of commercial buildings that could house a small business based on the small business employment share by industry for 2015 (see Table 11.2.2).[4]

Table 11.2.2 Fraction of Small Business Employment Share by Industry, 2015

Industry (CBECS Principal Building Activity)	Fraction of Small Business Employment Share (%)
Real estate investment trust (REIT)	68.3
Outpatient health care	45.2
Public assembly	61.4
Inpatient health care	45.2
Lodging	60.6

In general, smaller businesses tend to discount future stream of monetary flows at higher rates. Table 11.2.3 presents DOE's estimates of the discount rates for entire sectors and small companies specifically. DOE conducted a subgroup analysis for small businesses, and subsequently the results of the subgroup analysis were compared to the results from all customers. To estimate the impact of standards specifically on small businesses, the small company discount rates for each sector were used in the life-cycle cost and payback period analysis instead of the sector average discount rates.

Table 11.2.3 Discount Rate Difference between Small Company and Sector Average

Sector with a Pool Heater	Average Discount Rate (%)		
	Entire Sector	Small Business	Small Business Differential
Real estate investment trust (REIT)	6.43	8.78	2.35
Outpatient health care	6.78	9.60	2.82
Public assembly	7.17	9.96	2.79
Inpatient health care	6.78	9.60	2.82
Lodging	6.35	8.67	2.32
State/Local/Public Edu*	3.21	--	--
Federal Gov.*	2.17	--	--

* Note that it is not appropriate to calculate a separate small company discount rate for public sectors.

11.2.3 Estimation of Impacts

To calculate the subgroup results, DOE extracted the results of senior-only households from the national LCC results. Then DOE calculated the LCC and PBP statistics for the subgroup from the individual households.

11.3 RESULTS

11.3.1 Electric Pool Heaters

Table 11.3.1 and Table 11.3.2 summarize the LCC and PBP results for electric pool heaters for senior-only households. Table 11.3.3 and Table 11.3.4 summarize the LCC and PBP results for electric pool heaters for small business.

Table 11.3.1 Average LCC and PBP Results by Efficiency Level for Electric Pool Heaters for Senior-Only Households

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99%	3,572	1,002	8,655	12,227	NA	11
1	387%	3,983	287	2,531	6,514	0.6	11
2	483%	4,092	239	2,119	6,211	0.7	11
3	534%	4,192	220	1,962	6,153	0.8	11
4	551%	4,337	215	1,916	6,253	1.0	11
5	595%	4,530	209	1,864	6,394	1.2	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.2 LCC Savings Relative to the Base Case Efficiency Distribution for Electric Pool Heaters for Senior-Only Households

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	99%	NA	0%
1	387%	3,560	1%
2	483%	1,635	3%
3	534%	309	34%
4	551%	176	57%
5	595%	19	78%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 11.3.3 Average LCC and PBP Results by Efficiency Level for Electric Pool Heaters for Small Business

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99%	3,688	6,484	34,390	38,078	NA	11
1	387%	4,977	1,746	8,877	13,854	0.3	11
2	483%	5,094	1,463	7,303	12,396	0.3	11
3	534%	5,196	1,337	6,616	11,812	0.3	11
4	551%	5,346	1,275	6,311	11,656	0.3	11
5	595%	5,545	1,207	5,993	11,538	0.4	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.4 LCC Savings Relative to the Base Case Efficiency Distribution for Electric Pool Heaters for Small Business

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	99%	NA	0%
1	387%	$19,451	6%
2	483%	$19,457	6%
3	534%	$11,380	10%
4	551%	$11,087	15%
5	595%	$10,469	27%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, *i.e.,* those with zero LCC savings.

11.3.2 Gas-fired Pool Heaters

Table 11.3.5 and Table 11.3.6 summarize the LCC and PBP results for gas-fired pool heaters for senior-only households. Table 11.3.7 and Table 11.3.8 summarize the LCC and PBP results for gas-fired pool heaters for small business.

Table 11.3.5 Average LCC and PBP Results by Efficiency Level for Gas-fired Pool Heaters for Senior-Only Households

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	69.7%	3,237	494	4,595	7,832	NA	11
1	81.3%	3,250	406	3,763	7,012	0.1	11
2	83.3%	3,490	401	3,725	7,215	2.7	11
3	94.7%	4,388	376	3,534	7,922	9.7	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.6 LCC Savings Relative to the Base Case Efficiency Distribution for Gas-fired Pool Heaters for Senior-Only Households

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	69.7%	NA	0%
1	81.3%	752	0%
2	83.3%	(132)	49%
3	94.7%	(788)	89%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 11.3.7 Average LCC and PBP Results by Efficiency Level for Gas-fired Pool Heaters for Small Business

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	69.7%	$3,661	$9,546	$67,510	$71,171	NA	11
1	81.3%	$3,675	$9,523	$67,299	$70,974	0.6	11
2	83.3%	$4,109	$9,332	$65,941	$70,050	2.1	11
3	94.7%	$5,156	$8,392	$59,243	$64,400	1.3	11

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 11.3.8 LCC Savings Relative to the Base Case Efficiency Distribution for Gas-fired Pool Heaters for Small Business

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	69.7%	NA	0%
1	81.3%	$151	0%
2	83.3%	$821	13%
3	94.7%	$5,572	19%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, *i.e.,* those with zero LCC savings.

11.3.3 Comparison of Senior-Only and Small Business to the General Population

Table 11.3.9 and Table 11.3.10 compare the LCC savings and simple payback period for the considered subgroup with those for all households with gas-fired pool heaters and electric pool heaters, respectively. In most cases, the average LCC savings and PBP for senior-only households at the considered efficiency levels are substantially different from the average for all households, since all households includes consumer pool heaters in commercial applications.

Table 11.3.9 Comparison of Average LCC Savings for Consumer Subgroups and All Households for Electric Pool Heaters

Efficiency Level	TE_i %	Average Life-Cycle Cost Savings* *2021$*			Simple Payback Period *years*		
		Senior Only	Small Business	All Households	Senior Only	Small Business	All Households
1	387%	3,560	19,451	8,090	0.6	0.3	0.3
2	483%	1,635	19,457	4,403	0.7	0.3	0.4
3	534%	309	11,380	1,302	0.8	0.3	0.4
4	551%	176	11,087	1,130	1.0	0.3	0.5
5	595%	19	10,469	946	1.2	0.4	0.6

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.
* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, *i.e.,* those with zero LCC savings.

Table 11.3.10 Comparison of Average LCC Savings for Consumer Subgroups and All Households for Gas-fired Pool Heaters

Efficiency Level	TE_i %	Average Life-Cycle Cost Savings* *2021$*			Simple Payback Period *years*		
		Senior Only	Small Business	All Households	Senior Only	Small Business	All Households
1	81.3%	752	151	783	0.1	0.6	0.2
2	83.3%	(132)	821	80	2.7	2.1	2.3
3	94.7%	(788)	5,572	497	9.7	1.3	4.2

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.
* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, *i.e.,* those with zero LCC savings.

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether standards are economically justified, the U.S. Department of Energy (DOE) is required to consider "the economic impact of the standard on the manufacturers and on the consumers of the products subject to such a standard." (42 U.S.C. 6312(a)(6)(B)(i)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. Id. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of new and amended energy conservation standards on manufacturers of pool heaters and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for the products in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of new and amended energy conservation standards by comparing changes in INPV between the no-new-standards case and the various trial standard levels (TSLs) in the standards cases. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, market and product trends, as well as the impact of standards on subgroups of manufacturers, including small manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in phases. Phase I, "Industry Profile," consisted of preparing an industry characterization for the consumer pool heater industry. This characterization included data on sales volumes, pricing, employment, and financial structure. In phase II, "Industry Cash Flow Analysis," DOE used the GRIM to assess the potential impacts of amended energy conservation standards on manufacturers. In phase III, "Subgroup Impact Analysis," DOE developed additional analyses for subgroups that may be affected in various ways. Each phase of the MIA is described in greater detail in the following sections.

12.2.1 Phase I: Industry Profile

In phase I of the MIA, DOE prepared a profile of the consumer pool heater industry that built on the market and technology assessment (MTA) prepared for this rulemaking (refer to chapter 3 of this technical support document (TSD). Before initiating detailed impact analyses, DOE collected information on past and present market characteristics of the consumer pool heater industry. This information included shipment data, manufacturer markups, manufacturer market shares, and consolidation trends. As part its industry profile research, DOE also collected information on industry financial parameters, such as net plant, property, and equipment (PPE); selling, general and administrative (SG&A) expenses; research and development (R&D) expenses, depreciation, revenue, cost of goods sold, etc. These parameters allowed DOE to derive preliminary industry financial inputs for the GRIM as discussed in section 12.3.4.

DOE used public information to develop its initial characterization of the industry, including Securities and Exchange Commission (SEC) 10-K reports,[1] Standard & Poor's (S&P)

stock reports,[2] market research tools (*i.e.*, D&B Hoovers[3]), corporate annual reports, and the U.S. Census Bureau's 2020 Annual Survey of Manufacturers (ASM).[4] DOE also used information from its engineering analysis to enhance its industry profile.

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II focused on the financial impacts of new and amended energy conservation standards on manufacturers of consumer pool heaters. More stringent energy conservation standards can affect manufacturer cash flows in three distinct ways. These include: (1) creating a need for increased investment; (2) raising production costs per unit; and (3) altering revenue due to higher per-unit prices and/or possible changes in sales volumes. To quantify these impacts, DOE used the GRIM to perform a cash-flow analysis for the consumer pool heater industry. DOE used the financial values derived during phase I and the shipment scenarios used in the national impact analysis (NIA) to perform these analyses. The GRIM modeled impacts for all the analyzed TSLs.

12.2.2.1 Industry Cash-Flow Analysis

The GRIM is designed to take into account several factors while calculating a series of annual cash flows from the announcement year of new and amended energy conservation standards until 30 years after the compliance date. These factors include annual expected revenues, costs of goods sold, SG&A, taxes, and capital expenditures related to the new and amended standards. DOE developed these financial parameters using publicly available manufacturer data. DOE also used estimates developed in other analyses as inputs to the GRIM, including manufacturer production costs (MPCs) and shipments forecasts. DOE derived the MPCs from the engineering analysis. DOE estimated typical manufacturer markups from publicly available financial reports and refined these markups during manufacturer interviews. DOE developed alternative manufacturer markup scenarios in the standards cases used in the GRIM to estimate the range of potential impacts on manufacturers. DOE's shipments analysis, presented in chapter 9 of the TSD, provided the basis for the shipment projections used in the GRIM. Once the GRIM was complete, DOE compared the results at various TSLs to no-new-standards-case projections for the industry. The difference between the discounted annual cash flows in the no-new-standards-case and standards case at each TSL represents the financial impact of new and amended standards on the industry.

12.2.3 Phase III: Subgroup Analysis

In phase III of its analysis, DOE identified any subgroups of consumer pool heater manufacturers that may be affected in different ways by amended standards. DOE identified two manufacturer subgroups that could be disproportionately affected by new and amended standards: small business manufacturers and electric consumer pool heater manufacturers. As a result, DOE conducted a separate analysis for small businesses and electric consumer pool heater manufacturers.

12.2.3.1 Manufacturer Subgroup Analysis

DOE acknowledges that using average cost assumptions to develop industry cash-flow estimates may not adequately assess different impacts of new and amended energy conservation standards on manufacturer subgroups. For example, small manufacturers, niche players, or manufacturers exhibiting a cost structure that largely differs from the industry average, could be more negatively affected.

DOE identified one manufacturer subgroup for consumer pool heater manufacturers: small business manufacturers.

While DOE presents the industry impacts on consumer pool heater manufacturers as a whole in this final rule in section 12.4, DOE also presents the industry impacts on small business manufacturers in section 12.5.

Small Business Manufacturer Subgroup

DOE first investigated whether small business manufacturers should be analyzed as a manufacturer subgroup. DOE used the U.S. Small Business Administration (SBA) small business size standards, effective October 1, 2022, as amended, and the North American Industry Classification System (NAICS) code, presented in Table 12.2.1, to determine whether any small entities would be affected by the rulemaking.[5] For the product classes under review, the SBA bases its small business definition on a company's total number of employees. This includes its subsidiaries and its parent companies. An aggregated business entity with fewer employees than the listed limit is considered a small business.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by this Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Heating Equipment (except Warm Air Furnaces) Manufacturing	N/A	500	333414

DOE used publicly available information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (*e.g.,* Air-Conditioning, Heating, and Refrigeration Institute (AHRI)[6]), information from previous rulemakings, individual company websites, and market research tools (*e.g.,* D&B Hoover's reports) to create a list of companies that manufacture consumer pool heaters. DOE used information from these sources to create a list of companies that manufacture or sell products covered by this rulemaking. DOE screened out companies that did not offer products covered by this rulemaking, did not meet the definition of a small business, or are foreign owned and operated.

Based on this analysis, DOE identified six companies that meet SBA's definition of a small business. All six domestic small businesses only manufacture electric pool heaters. DOE did not identify any domestic small businesses that manufacture gas-fired pool heaters.

12.2.3.2 Manufacturing Capacity Impact

New and amended energy conservation standards could result in the obsolescence of existing manufacturing assets, including tooling and capital investments. DOE analyzed manufacturer capacity utilization and plant location decisions in the United States, with and without new and amended standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new efficiency requirements; the nature and value of any stranded assets that might result from new and amended standards; and estimates for any one-time changes to existing PPE that be necessitated by new and amended standards. DOE's estimates of the one-time capital changes and stranded assets affect the cash flow estimates in the GRIM. These estimates can be found in section 12.3.8. DOE's discussion of the manufacturing capacity impact can be found in section 12.6.2.

12.2.3.3 Direct Employment Impact

The impact of new and amended energy conservation standards on employment is an important consideration in the rulemaking process. To assess how domestic direct employment patterns might be affected, DOE obtained data from the U.S. Census Bureau's 2020 ASM about current direct employment trends in the consumer pool heater industry. The employment impacts are reported in section 12.6.1.

12.2.3.4 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers due to new and amended energy conservation standards and other regulatory actions affecting the same products. DOE analyzed the impact on manufacturers of multiple Federal, product-specific regulatory actions. Based on its own research, DOE identified ongoing rulemakings relevant to consumer pool heater manufacturers, including other Federal regulations that affect other products made by the same manufacturers. Discussion of the cumulative regulatory burden can be found in section 12.6.3.

12.3 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to new and amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. DOE then feeds data and assumptions from these sources into an accounting model that calculates the industry cash flow both with and without new and amended energy conservation standards.

12.3.1 Overview of the Government Regulatory Impact Model

The basic structure of the GRIM, illustrated in Figure 12.3.1, is an annual cash-flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses these and other inputs to calculate a series of annual cash flows, beginning with the base year of the analysis, 2023, and continuing to 2057. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[7]

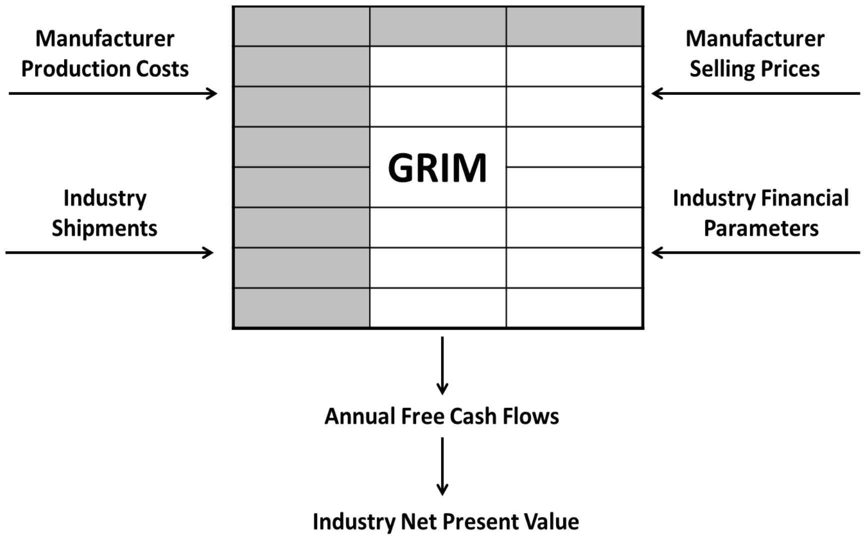

Figure 12.3.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares changes in INPV between the no-new-standards-case scenario and the standards-case scenario induced by new and amended energy conservation standards. The difference in INPV between the no-new-standards-case and the standards case represents the estimated financial impact of new and amended energy conservation standards on manufacturers. Appendix 12A provides more technical details and user information for the GRIM.

12.3.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include corporate annual reports, company profiles, census data, credit ratings, the shipments model, the engineering analysis, and manufacturer interviews.

12.3.2.1 Corporate Annual Reports

Corporate annual reports to the SEC (SEC 10-Ks) provided many of the initial financial inputs to the GRIM. These reports exist for publicly held companies and are available to the public. DOE developed initial financial inputs to the GRIM by examining the annual SEC 10-K reports filed by publicly traded consumer pool heater manufacturers. DOE generally has to use parent-company-level financial data to develop its initial financial parameter estimates for the GRIM, as these companies do not usually provide detailed financial information about their individual product lines in their 10-K reports. These estimates were revised using feedback from manufacturer interviews to be representative of consumer pool heaters. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate
- Working capital
- SG&A
- R&D
- Depreciation

- Capital expenditures
- Net PPE

12.3.2.2 Standard and Poor Credit Ratings

S&P provides independent credit ratings, research, and financial information. DOE relied on S&P reports to determine the industry's average cost of debt when calculating the cost of capital.

12.3.2.3 Shipment Model

DOE used shipment projections derived from DOE's shipments model in the NIA in the GRIM analysis. Chapter 9 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

12.3.2.4 Engineering Analysis

The engineering analysis develops the relationship between the MPC and energy efficiency for the products analyzed in this rulemaking. This relationship serves as the basis for the cost-benefit calculations for consumers, manufacturers, and the nation. In determining the cost-efficiency relationship, DOE estimates the increase in MPC associated with increasing the efficiency of product above the baseline up to the maximum technologically feasible (max-tech) efficiency level for each product class.

DOE conducted this engineering analysis for consumer pool heaters using an efficiency-level approach to determine the efficiency levels for analysis and performed physical teardowns for the cost analysis. Chapter 5 of the TSD describes the methodology DOE used to conduct the engineering analysis.

12.3.3 Trial Standard Levels

DOE developed efficiency levels for each product class. TSLs were then developed by selecting groupings of efficiency levels for both product types. Table 12.3.1 presents the TSLs examined as part of this rulemaking.

Table 12.3.1 Trial Standard Levels for Consumer Pool Heaters by Efficiency Level

Product Class	TSL 1	TSL 2	TSL 3	TSL 4	TSL 5	TSL 6
PC1: Consumer gas-fired pool heater	EL 1	EL 1	EL 1	EL 1	EL 2	EL 3
PC2: Consumer electric pool heaters	EL 1	EL 2	EL 3	EL 4	EL 4	EL 5

12.3.4 Financial Parameters

As part of the MIA, DOE estimated eight key financial parameters for use in the GRIM. DOE developed its initial estimates of industry financial parameters based the SEC 10-Ks and revised these based on feedback form manufacturers during manufacturer interviews.

Table 12.3.2 presents the financial parameters used as inputs to the GRIM.

Table 12.3.2 Financial Parameters for the Consumer Pool Heaters Industry

Financial Parameter	Estimate (%)
Tax Rate (% of taxable income)	21.0
Discount Rate	7.4
Working Capital (% of Revenue)	16.0
Net Property, Plant, and Equipment (% of Revenue)	13.0
SG&A (% of Revenue)	17.7
R&D (% of Revenue)	2.0
Depreciation (% of Revenue)	2.2
Capital Expenditures (% of Revenue)	2.0

12.3.5 Manufacturer Markup

DOE also used publicly available financial data to estimate an average manufacturer markup for the consumer pool heater industry. In the April 2022 NOPR analysis DOE used a manufacturer markup of 1.33 for gas-fired consumer pool heaters and a manufacturer markup of 1.28 for electric consumer pool heaters. 87 FR 22640, 22686 DOE revisited all publicly traded consumer pool heater manufacturer's financial statements for the past 5 years. For this time frame, all publicly traded consumer pool heater manufacturers had a corporate-level manufacturer markups greater than 1.33 (the highest manufacturer markup used in the April 2022 NOPR analysis) and during manufacturer interviews conducted after the publication of the April 2022 NOPR, all manufacturers stated that the manufacturer markups used in the April 2022 NOPR analysis should be increased. DOE recognizes that corporate-level manufacturer markups can significantly vary by products (for manufacturers that manufacture multiple products). However, DOE revised the manufacturer markups for this final rule analysis, based on the public corporate-level data and the confidential product-specific data provided by manufacturers during manufacturer interviews. DOE increased the gas-fired consumer pool heater manufacturer markup from 1.33 used in the April 2022 NOPR analysis to 1.44 and increased the electric consumer pool heater manufacturer markup from 1.28 used in the April 2022 NOPR analysis to 1.39 for this final rule analysis. This markup captures all non-production costs, including SG&A expenses, R&D expenses, interest, and profit. Table 12.3.3 presents the manufacturer markups used as inputs to the GRIM in both the April 2022 NOPR and this final rule analysis.

Table 12.3.3 No-New-Standards Case Manufacturer Markups

Product Class	Manufacturer Markup	
	NOPR	Final Rule
PC1: Consumer gas-fired pool heaters	1.33	1.44
PC2: Consumer electric pool heaters	1.28	1.39

12.3.6 Shipment Forecasts

The GRIM estimates manufacturer revenues based on total unit shipment forecasts and the distribution of these values by efficiency level. Changes in sales volumes and efficiency mix over time can significantly affect manufacturer finances. For this analysis, the GRIM uses the NIA's annual shipment forecasts derived from the shipments analysis from 2023 (the base year) through 2057 (the end year of the analysis period). See chapter 9 of the TSD for more information on the standards-case shipment forecasts.

12.3.7 Manufacturer Production Costs

Manufacturing higher efficiency product is typically more expensive than manufacturing baseline product due to the use of more complex components, which are typically more costly than baseline components. The changes in the MPCs of the analyzed product can affect the revenues, gross margins, and cash flow of the industry, making these product cost data key GRIM inputs for DOE's analysis.

DOE used information from its teardown analysis to disaggregate the MPCs into material, labor, depreciation, and overhead costs. To calculate the MPCs for products above the baseline, DOE added incremental material, labor, depreciation, and overhead costs from the engineering cost-efficiency curves to the baseline MPCs. These cost breakdowns were validated with manufacturers during manufacturer interviews.

12.3.8 Conversion Costs

New and amended energy conservation standards could cause manufacturers to incur conversion costs to bring their production facilities and product designs into compliance. DOE evaluated the level of conversion-related expenditures that would be needed to comply with each considered efficiency level in each product class. For the MIA, DOE classified these conversion costs into two major groups: (1) product conversion costs; and (2) capital conversion costs. Product conversion costs are investments in research, development, testing, marketing, and other non-capitalized costs necessary to make product designs comply with new and amended energy conservation standards. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new compliant product designs can be fabricated and assembled.

To evaluate the level of capital conversion costs manufacturers would likely incur to comply with new and amended energy conservation standards, DOE used data gathered from manufacturer interviews as well as information derived from the product teardown analysis and engineering model. In developing its conversion cost estimates, DOE conservatively assumed manufacturers would redesign all noncompliant consumer gas-fired and heat pump pool heaters to comply with new and amended energy conservation standards (electric resistance pool heaters are discussed further in this section). Manufacturers could choose to drop some models that do not meet the levels prescribed by new and amended standards. Therefore, total product and capital conversion costs may be lower than the estimates calculated as part of this analysis.

After the April 2022 NOPR was published, DOE interviewed several manufacturers to discuss specific conversion costs their companies would likely incur at each efficiency level.

Based on these manufacturer interviews, DOE updated the conversion cost estimates for this final rule analysis based on comments regarding the April 2022 NOPR and the confidential manufacturer interviews conducted after the publication of the April 2022 NOPR.

Product conversion costs are calculated on a per model basis and are primarily driven by engineering R&D costs and testing costs. R&D costs include engineering time necessary to redesign non-compliant consumer pool heater models. DOE assumed that manufacturers would discontinue all their electric resistance consumer pool heater models for any standard level above baseline for electric consumer pool heaters, because electric resistance consumer pool heaters use different technologies and designs than heat pump consumer pool heaters. Consequently, no redesign costs are assigned to the redesign of electric resistance consumer pool heater models.

For heat pump consumer pool heaters, all design options include growing the size of the evaporator. DOE assumed that the per model redesign effort, for electric heat pump consumer pool heaters, is the same to redesign a product to meet EL 2 and EL 3 but would require more engineering design time to redesign a product to meet EL 4 and EL 5. However, the number of models that would be required to be redesigned would vary for each EL required by the analyzed standard. In the April 2022 NOPR analysis, DOE estimated six months of engineering time per model for electric heat pump consumer pool heaters to meet all analyzed ELs. 87 FR 22640, 22684-5. However, based on confidential interviews with manufacturers conducted after the publication of the April 2022 NOPR, manufacturers stated that there would be a higher per model redesign effort to meet standards at EL 4 and EL 5, compared to meeting standards at EL 2 or EL 3. Manufacturers stated that more complicated engineering designs would be required to be used at EL 4 and EL 5 as well as tighter manufacturing tolerances that would require more engineering time. Therefore, DOE increased the engineering effort for electric heat pump consumer pool heaters to meet EL 4 and EL 5. For this final rule, DOE estimated a redesign effort of six months of engineering time per model for electric heat pump consumer pool heaters to meet EL 2 and EL 3 (the same estimate used in the April 2022 NOPR), and 12 months of engineering time per model to meet EL 4 and EL 5 (based on feedback provided during confidential manufacturer interviews).

For gas-fired consumer pool heaters, DOE estimated that the redesign effort varies for each efficiency level. The design option analyzed at EL 1 replaces the standing pilot with an electronic ignition system. This entails a component swap and requires the addition of a sparker. DOE estimates a total of two months of engineering time per model to redesign a model with a standing pilot to an electronic ignition. The design option analyzed at EL 2 incorporates a blower. Product conversion costs involve the selection, qualification, and safety testing of the blower. In the April 2022 NOPR analysis DOE estimated 18 months of engineering time per model to meet EL 2, and 24 months of engineering time per model to meet EL 3 for gas-fired consumer pool heaters. 87 FR 22640, 22685. However, based on confidential interviews with manufacturer conducted after the publication of the April 2022 NOPR, DOE increased the engineering effort for gas-fired consumer pool heaters to meet EL 2 and EL 3. Manufacturers stated that at EL 2 there would be a much smaller margin between the standards required at EL 2 and levels gas-fired pool heater will condense. Therefore, there will be a significant engineering effort to ensure both product reliability and compliance at EL 2. Therefore, in this Final Rule analysis, DOE estimated a redesign effort of 24 months of engineering time to redesign a gas-fired consumer pool heater model to meet EL 2 (per model). The design option analyzed at max-tech level incorporates condensing technology, which requires a significant amount of redesign to fine tune the gas-fired consumer pool heater such that it can accommodate condensate. Manufacturers stated that they will have to change the material for most of their heat exchangers, which would require substantially more resources than estimated in the April 2022 NOPR analysis. Therefore, in this Final Rule analysis, DOE estimated a redesign effort of 48 months of engineering time to redesign a gas-fired consumer pool heater model to meet EL 3 (per model). Based on this additional, and more recent, information provided during manufacturers interviews DOE increased the estimated per model conversion costs for gas-fired consumer pool heaters at EL 2 and EL 3.

In addition to these redesign costs, DOE estimated a variety of testing costs including certification testing, verification testing, and combustion and emissions testing (for gas-fired consumer pool heaters). DOE estimated that gas-fired consumer pool heaters would require approximately 100 hours of testing to meet EL 1; 1,200 hours of testing to meet EL 2; and 3,500 hours of testing to meet EL 3 for each model that would need to be redesigned due to energy conservation standards. These testing costs include engineers, lab technicians, and all other employees involved in the testing process. For electric heat pump consumer pool heaters DOE estimated testing costs would be approximately $6,500 per model for all efficiency levels analyzed that would need to be redesigned due to energy conservation standards.

Capital conversion costs are estimated on a per manufacturer basis. DOE developed a list of manufacturers of gas-fired, heat pump, and electric resistance consumer pool heaters using manufacturer's websites and public databases such as AHRI, DOE's publicly available CCD, and CEC's MAEDbS. For gas-fired consumer pool heaters, capital conversion costs would not be required at EL 1 since manufacturers would likely meet this EL by switching the ignition system from a standing pilot to electronic ignition. This is a component swap and likely would not require any capital investments. At EL 2, DOE estimated each manufacturer making gas-fired consumer pool heaters would be required to invest approximately $1 million per manufacturer to incorporate the blower that would likely be needed to meet this EL. At EL 3, manufacturers would likely be required to use condensing technology to meet this EL. This would require larger investments from manufacturers to necessitate major changes to tooling to make condensing heat exchangers as well as changes to injection molding machinery to accommodate larger cabinet sizes. At EL 2, DOE estimated each manufacturer making gas-fired consumer pool heaters would be required to invest approximately $4 million per manufacturer to incorporate condensing technology for all gas-fired consumer pool heater models manufactured. This $4 million investment per manufacturer would be in addition to the $1 million required to achieve EL 2.

For electric heat pump consumer pool heaters, DOE estimated that a manufacturer that makes their own heat exchangers would be required to make approximately $2.5 million in capital investments (per manufacturer) to meet EL 3 and above. For a manufacturer that does not make their own heat exchangers, would be required to make approximately $130,000 in tooling costs to be able to incorporate a larger heat exchanger into their products.

Lastly, for this final rule analysis DOE updated the model database of consumer pool heaters from the database that was used in the NOPR analysis, to reflect all consumer pool heater models that are currently available on the market. DOE used the most recent data available from

DOE's CCD, CEC's MAEDbS, and AHRI's certification database for this final rule analysis. DOE identified a total of 79 unique basic models for gas-fired consumer pool heaters, 190 unique basic models for electric heat pump consumer pool heaters, and 20 unique basic models for electric resistance consumer pool heaters. These unique basic model counts, along with their estimated ELs, were used when estimating the total industry product and capital conversion costs used in this final rule analysis.

DOE assumed all conversion costs will occur between the year of publication of the final rule and the year by which manufacturers must comply with new and amended energy conservation standards. Additionally, for the final rule analysis DOE updated the conversion cost estimates from 2020 dollars into 2021 dollars.

The conversion cost estimates used in the GRIM can be found in Table IV.17 and in section IV.J.2.c of this document. For additional information on the estimated capital and product conversion costs, see chapter 12 of the final rule TSD.

Table 12.3.4 Industry Product and Capital Conversion Costs per Efficiency Level

	Units	Product Class	Efficiency Levels				
			EL 1	**EL 2**	**EL 3**	**EL 4**	**EL 5**
Product Conversion Costs	*2021$ millions*	Gas-Fired	$0.1	$14.1	$63.1		
		Electric	$1.2	$2.6	$9.0	$19.9	$24.8
Capital Conversion Costs	*2021$ millions*	Gas-Fired	$0.0	$5.0	$29.0		
		Electric	$0.0	$0.8	$9.5	$9.5	$9.5

12.3.9 Markup Scenarios

DOE modeled two manufacturer markup scenarios to capture uncertainty regarding potential impacts on prices and profitability following implementation of new and amended energy conservation standards: (1) preservation of gross margin scenario and (2) a preservation of operating profit scenario. These scenarios lead to different manufacturer markups that, when applied to MPCs, result in varying revenue and cash flow impacts.

12.3.9.1 Preservation of Gross Margin Scenario

Under the preservation of gross margin scenario, DOE applied a single uniform "gross margin" across all efficiency levels, which assumes that manufacturers would be able to maintain the same amount of profit as a percentage of revenues at all efficiency levels within a product class. As MPCs increase with efficiency, this scenario implies that the absolute dollar markup will increase as well. Therefore, DOE assumes that this scenario represents the upper bound to industry profitability under energy conservation standards.

As stated in section 12.3.5, DOE use a manufacturer markup of 1.44 for gas-fired consumer pool heaters and a manufacturer markup of 1.39 for electric consumer pool heaters.

12.3.9.2 Preservation of Operating Profit Scenario

Under the preservation of operating profit scenario, DOE modeled a situation in which manufacturers are not able to increase per-unit operating profit in proportion to increases in MPCs. Under this scenario, as the MPCs increase, manufacturers are generally required to reduce the manufacturer markup to maintain a cost competitive offering in the market. Therefore, gross margin (as a percentage) shrinks in the standards cases. This manufacturer markup scenario represents the lower bound to industry profitability under new and amended energy conservation standards.

For consumer pool heaters, Table 12.3.5 and Table 12.3.6 list the product classes DOE analyzed with the corresponding preservation of operating profit markups at each analyzed efficiency level.

Table 12.3.5 Preservation of Operating Profit for Gas-Fired Consumer Pool Heaters

Efficiency Level	Markups by Selected EL			
	Baseline	EL 1	EL 2	EL 3
Baseline	1.440			
EL 1	1.440	1.440		
EL 2	1.440	1.440	1.420	
EL 3	1.440	1.440	1.440	1.377

Table 12.3.6 Preservation of Operating Profit for Electric Consumer Pool Heaters

Efficiency Level	Markups by Selected EL					
	Baseline	EL 1	EL 2	EL 3	EL 4	EL 5
Baseline	1.390					
EL 1	1.390	1.379				
EL 2	1.390	1.390	1.386			
EL 3	1.390	1.390	1.390	1.382		
EL 4	1.390	1.390	1.390	1.390	1.376	
EL 5	1.390	1.390	1.390	1.390	1.390	1.369

12.4 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in previous sections, DOE estimated financial impacts on the consumer pool heater industry resulting from new and amended energy conservation standards. The following sections address two key financial metrics analyzed in the MIA: industry net present value and annual cash flows.

12.4.1 Impacts on Industry Net Present Value

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs. The INPV is the sum of all net cash flows discounted at the industry's cost of capital or discount rate. The GRIM for this rulemaking estimates cash flows from 2023 to 2057. This timeframe models both the short-term impacts on the industry from the base year of the analysis until the compliance date (2023–2028) and the long-term impacts over the 30-year analysis period used in the NIA (2028–2057).

In the MIA, DOE compares the INPV in the no-new-standards-case to the INPVs that result at each TSL in the standards case. The difference between these estimates represents the economic impacts implementing a particular TSL would have on the industry. For the consumer pool heater industry, DOE examined the two manufacturer markup scenarios described in section 12.3.9, which result in a range of INPV impacts at each TSL. Table 12.4.1 and Table 12.4.2 show the estimated INPV impacts under the two scenarios.

Table 12.4.1 Manufacturer Impact Analysis Results: Preservation of Gross Margin Scenario

	Units	No-New-Standards Case	Trial Standard Level*					
			1	**2**	**3**	**4**	**5**	**6**
INPV	*2021$ millions*	585.7	585.2	584.5	577.0	575.0	587.7	631.6
Change in INPV	*2021$ millions*	-	(0.6)	(1.2)	(8.7)	(10.7)	2.0	45.9
	%	-	(0.1)	(0.2)	(1.5)	(1.8)	0.3	7.8
Product Conversion Costs	*2021$ millions*	-	1.3	2.6	9.1	20.0	34.0	88.0
Capital Conversion Costs	*2021$ millions*	-	-	0.8	9.5	9.5	14.5	38.5
Total Conversion Costs	*2021$ millions*	-	1.3	3.4	18.6	29.4	48.4	126.4

* Parentheses indicate negative values.

Table 12.4.2 Manufacturer Impact Analysis Results: Preservation of Operating Profit Scenario

	Units	No-New-Standards Case	Trial Standard Level*					
			1	2	3	4	5	6
INPV	*2021$ millions*	585.7	583.6	581.9	570.8	563.0	548.4	482.7
Change in INPV	*2021$ millions*	-	(2.2)	(3.9)	(15.0)	(22.8)	(37.3)	(103.0)
	%	-	(0.4)	(0.7)	(2.6)	(3.9)	(6.4)	(17.6)
Product Conversion Costs	*2021$ millions*	-	1.3	2.6	9.1	20.0	34.0	88.0
Capital Conversion Costs	*2021$ millions*	-	-	0.8	9.5	9.5	14.5	38.5
Total Conversion Costs	*2021$ millions*	-	1.3	3.4	18.6	29.4	48.4	126.4

* Parentheses indicate negative values.

12.4.2 Impacts on Annual Cash Flow

While INPV is useful for evaluating the long-term effects of new and amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's access to capital. Consequently, a sharp drop in financial performance could cause investors to flee, even though recovery may be possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To illustrate this possible short-term disturbance, Figure 12.4.1 and Figure 12.4.2 present annual net cash flows in the no-new-standards-case and for each TSL in the standards case. In addition, Table 12.4.3 presents estimated free cash flow impacts in the year prior to the standard (2027).

Annual cash flows are discounted to the reference year, 2022. After the standards announcement date, industry cash flows begin to decline as companies use their financial resources to prepare for the new and amended energy conservation standards. Cash flows between the announcement date and the compliance date are driven by the level of conversion costs and the proportion of these investments spent each year. The more stringent the energy conservation standard, and the higher the expected conversion costs, the greater the impact on industry cash flows in the years leading up to the compliance date. This is because product conversion costs increase operational expenses, thereby reducing net operating profit, while capital conversion costs increase capital expenses, resulting in higher cash outflows and further reducing free cash flow.

In the year new and amended standards take effect (2028), there is an increase in working capital that reduces cash flow from operations. A large increase in working capital is needed due to more costly production components and materials, carrying higher inventory to sell more expensive product, and higher accounts receivable for more expensive product.

Table 12.4.3 presents free cash flow impacts in the year before the standard takes effect. Figure 12.4.1 and Figure 12.4.2 graph the net annual cash flows for the two markup scenarios. While free cash flows vary over the course of the analysis period depending on the manufacturer markup scenario analyzed, they do not vary by manufacturer markup scenario in the years prior to the standard, as a shift in product mix and markup structure triggered by a standard has not yet taken effect.

Table 12.4.3 Industry Free Cash Flow Impacts in the Year before Compliance (2027)

	Units	No-New-Standards-Case	Trial Standard Level*					
			1	2	3	4	5	6
Free Cash Flow (2027)	*2021$ millions*	51.0	50.5	49.7	43.5	39.6	32.4	2.4
Change in Free Cash Flow	*2021$ millions*	-	(0.5)	(1.3)	(7.5)	(11.4)	(18.6)	(48.6)
	%	-	(0.9)	(2.5)	(14.7)	(22.3)	(36.5)	(95.3)

* Parentheses indicate negative values.

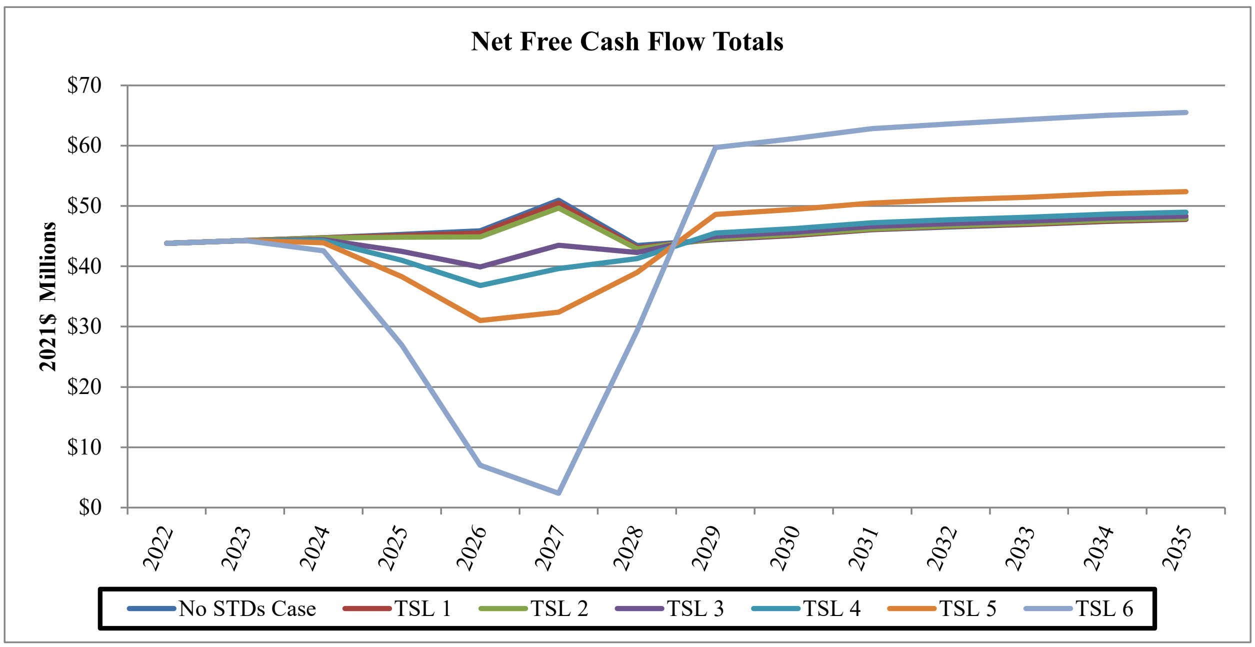

Figure 12.4.1 Annual Industry Net Cash Flows under the Preservation of Gross Margin Scenario

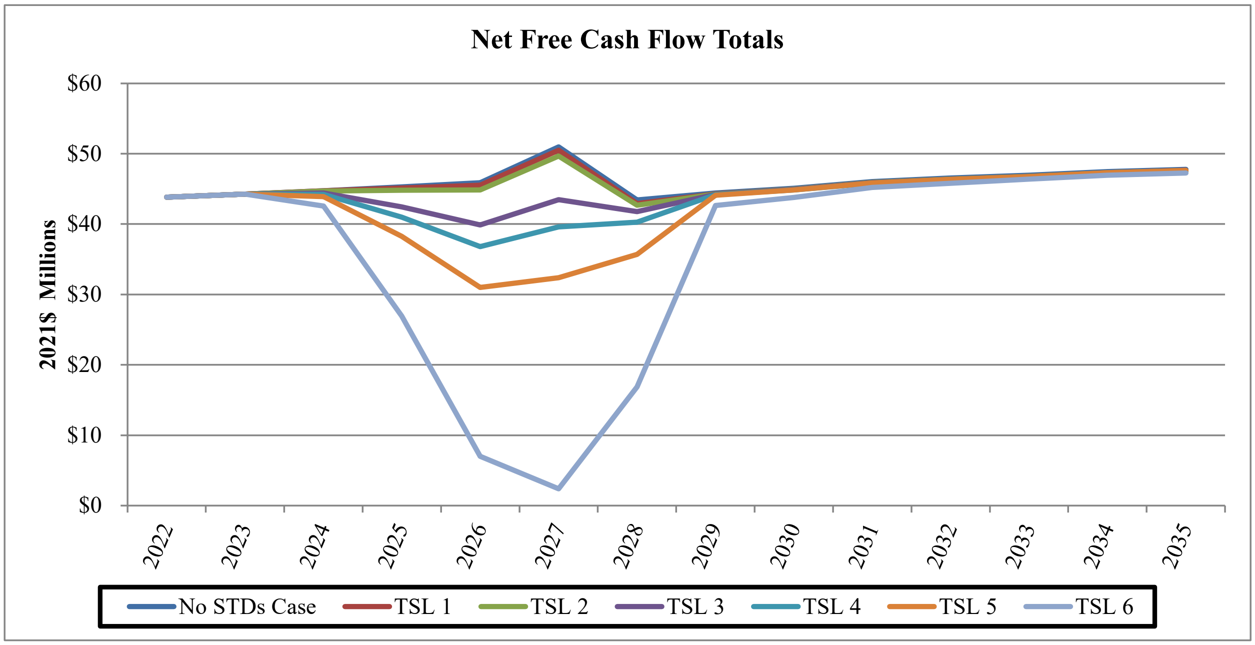

Figure 12.4.2 Annual Industry Net Cash Flows under the Preservation of Operating Profit Scenario

12.5 IMPACTS ON MANUFACTURER SUBGROUPS

As described in Section 12.2.3.1, DOE identified one manufacturer subgroup for consumer pool heater manufacturers: small business manufacturers. The results of this manufacturer subgroup analysis are described in the following section.

12.5.1 Impacts on Small Business Manufacturers

For manufacturers of consumer pool heaters, the SBA has set a size threshold, which defines those entities classified as "small businesses" for the purposes of the statute. DOE used the SBA's small business size standards to determine whether any small entities would be subject to the requirements of this proposed rule. See 13 CFR part 121. The size standards are listed by NAICS code and industry description and are available at www.sba.gov/document/support-table-size-standards.

Manufacturing of consumer pool heaters is classified under NAICS code 333414, "heating equipment (except warm air furnaces) manufacturing." The SBA sets a threshold of 500 employees or fewer for an entity to be considered as a small business for this category.

DOE reviewed the potential standard levels considered in this final rule under the provisions of the Regulatory Flexibility Act and the procedures and policies published on February 19, 2003. During its market survey, DOE used publicly available information to identify potential small manufacturers. DOE's research involved industry trade association membership directories (*e.g.,* AHRI), information from previous rulemakings, individual company websites, and market research tools (*e.g.,* D&B Hoover's reports) to create a list of companies that manufacture consumer pool heaters. DOE also asked stakeholders and industry representatives if they were aware of any additional small manufacturers during manufacturer interviews. DOE reviewed publicly available data and contacted various companies on its complete list of manufacturers to determine whether they met the SBA's definition of a small business manufacturer. DOE screened out companies that do not offer products impacted by this rulemaking, do not meet the definition of a "small business," or are foreign owned and operated.

DOE identified 20 companies manufacturing consumer pool heaters covered by this rulemaking. Of these manufacturers, DOE identified six companies that meet SBA's definition of a small business. All six domestic small businesses only manufacture electric pool heaters. DOE did not identify any domestic small businesses that manufacture gas-fired pool heaters.

DOE was able to reach and discuss potential standards with two of the six small businesses. Additionally, DOE requested information about small businesses and potential impacts on small businesses while interviewing large manufacturers.

Gas-fired pool heaters account for most of the consumer pool heater market, with approximately 72 percent of all consumer pool heater units shipped annually. Within the electric consumer pool heater market, approximately 92 percent of shipments are heat pump pool heaters and only a small fraction of the shipments are electric resistance consumer pool heaters. (See chapter 9 of the final rule TSD for more information on the shipments analysis conducted for this rulemaking.) Although the electric consumer pool heater market is smaller than the gas-fired consumer pool heater market, it is also more fragmented. Whereas DOE identified six manufacturers of gas-fired consumer pool heaters, DOE identified 18 manufacturers of electric consumer pool heaters (four of the companies make both gas-fired and electric consumer pool heaters).

Four manufacturers dominate the market for electric pool heaters, three large manufacturers and one small business. The rest of the market is served by a combination of large and small businesses with market shares estimated to be in the single digits. Of these manufacturers, DOE identified six as domestic small businesses. All six domestic small businesses only manufacture electric pool heaters. Of those six, five only manufacture electric heat pump pool heaters. The other small business only manufactures electric resistance pool heaters. DOE did not identify any domestic small businesses that manufacture gas-fired pool heaters.

DOE identified six small manufacturers of electric consumer pool heaters and no small manufacturers of gas-fired consumer pool heaters. Accordingly, this analysis of small business impacts focuses exclusively on the electric consumer pool heater industry.

This final rule adopts minimum energy conservation standards for electric consumer pool heaters at efficiency levels above those capable of being achieved by electric resistance pool heaters. Given that the designs of electric heat pump pool heaters and electric resistance pool heaters use different types of technology, DOE assumes manufacturers of electric resistance consumer pool heaters would discontinue those electric resistance consumer pool heater models rather than redesign them as electric heat pump consumer pool heaters. As a result, expected impacts on manufacturers vary based on the type of electric consumer pool heaters they manufacture.

There are two types of conversion costs that small businesses could incur due to the adopted standard for electric consumer pool heaters: product conversion costs and capital conversion costs. Product conversion costs are investments in R&D, testing, marketing, and other non-capitalized costs necessary to make product designs comply with new and amended energy conservation standards. Capital conversion costs are investments in property, plant, and equipment necessary to adapt or change existing production facilities such that new compliant product designs can be fabricated and assembled. Manufacturers will only need to make these investments if they have products that do not meet the adopted energy conservation standards. Testing costs are costs manufacturers must make to test their electric consumer pool heaters in accordance with DOE's test procedure to demonstrate compliance with adopted energy conservation standards. Manufacturers must do this for all compliant electric consumer pool heaters that are in the scope of this rulemaking.

DOE estimates there are two small businesses that do not have any electric heat pump consumer pool heater models that would meet the adopted standard for electric consumer pool heaters. DOE applied the conversion cost methodology described in section 12.3.8 to calculate each small business's estimate product and capital conversion costs. To calculate product conversion costs, DOE estimated it would take 12 months of engineering time to redesign a single electric heat pump consumer pool heater model to meet the adopted standards for electric consumer pool heater (EL 4). DOE estimates that there are approximately 50 electric heat pump consumer pool heater unique basic models manufactured by small businesses that may need to be redesigned to comply with the adopted energy conservation standard for electric consumer pool heaters. To calculate capital conversion costs DOE estimates that most small businesses would need to make investments in tooling to accommodate electric heat pump consumer pool heater models with a larger evaporator. Small business conversion costs are presented in Table 12.5.1.

The five small businesses that manufacture electric heat pump consumer pool heaters would incur testing costs to demonstrate compliance in accordance with DOE's test procedure to the electric consumer pool heater energy conservation standard. Electric consumer pool heaters are currently not subject to a DOE energy conservation standard. This final rule establishes new energy conservation standards for electric consumer pool heaters. Therefore, all manufacturers, including small businesses, will have to test all electric consumer pool heaters that are subject to this rulemaking after the compliance date of the energy conservation standards established in this final rule. DOE estimates that small businesses manufacture approximately 65 unique basic models of electric heat pump consumer pool heaters. All 65 electric heat pump consumer pool heater models will need to be tested after the compliance date. DOE estimates a per model testing cost for these electric heat pump consumer pool heater models of approximately $6,500 per model. Small business conversion and testing costs are presented in Table 12.5.1.

Table 12.5.1 Small Business Costs

	Small Business Costs *2021$ millions*	Average Cost per Small Business *2021$ millions*
Product Conversion Costs	$6.35	$1.27
Capital Conversion Costs	$0.65	$0.13
Testing Costs for Compliance	$0.42	$0.08
Total Small Business Costs	**$7.42**	**$1.48**

DOE estimates the average small business will incur approximately $1.48 million per small business. DOE assumes that all consumer pool heater manufacturers would spread these costs over the five-year compliance timeframe, as compliance with the standards adopted in this final rule is required within five years after the publication of this document. Therefore, DOE assumes that the average consumer pool heater small business would incur on average $296,000 annually in each of the five years leading up to the compliance date for consumer pool heaters. Using publicly available data, DOE estimated the average annual revenue of the five small businesses that manufacturer electric heat pump consumer pool heaters to be $13.7 million. Table 12.5.2 compares these average small business costs to average annual revenue of small businesses.

Table 12.5.2 Average Small Business Costs Compared to Annual Revenue

	Estimated Compliance Cost	Annual Revenue	Compliance Costs as a % of Annual Revenue	5 Years of Revenue	Compliance Costs as a % of 5 Years of Revenue
Units	*2021$ millions*	*2021$ millions*	%	*2021$ millions*	*%*
Average Small Business	$1.48	$13.7	10.8%	$68.5	2.2%

Lastly, for the one small business that manufactures only electric resistance consumer pool heaters, based on public company literature, this small business manufactures approximately nine electric resistance consumer pool heaters that would not be able to meet the adopted energy conservation standards for electric consumer pool heaters and therefore would no longer be allowed to sell these products in the United States. This small business also manufactures electric resistance spa heaters and commercial electric resistance heating products that would still be allowed to be sold in the United States, even after the compliance date of this final rule. This manufacturer's business and competitive position in the electric consumer pool heater market will be negatively impacted, since the adopted standards result in a minimum efficiency level that is not feasible for electric resistance pool heaters to achieve. This small business does not offer any compliant consumer pool heater products that could serve as a replacement product for the non-compliant electric resistance consumer pool heaters. However, this small business can still sell electric resistance spa heaters in the United States and will still be able to export electric resistance consumer pool heaters to other countries, including into Canada.

12.6 OTHER IMPACTS

12.6.1 Direct Employment

To quantitatively assess the potential impacts of new and amended energy conservation standards on direct employment in the consumer pool heaters industry, DOE used the GRIM to estimate the domestic labor expenditures and number of direct employees in the no-new-standards case and in each of the standards cases during the analysis period.

Production employees are those who are directly involved in fabricating and assembling products within an original equipment manufacturer facility. Workers performing services that are closely associated with production operations, such as materials handling tasks using forklifts, are included as production labor, as well as line supervisors.

DOE used the GRIM to calculate the number of production employees from labor expenditures. DOE used statistical data from the U.S. Census Bureau's 2019 Annual Survey of Manufacturers (ASM) and the results of the engineering analysis to calculate industry-wide labor expenditures. Labor expenditures related to product manufacturing depend on the labor intensity of the product, the sales volume, and an assumption that wages remain fixed in real terms over time. The total labor expenditures in the GRIM were then converted to domestic production employment levels by dividing production labor expenditures by the annual payment per production worker.

Non-production employees account for those workers that are not directly engaged in the manufacturing of the covered product. This could include sales, human resources, engineering, and management. DOE estimated non-production employment levels by multiplying the number of consumer pool heater production workers by a scaling factor. The scaling factor is calculated by taking the ratio of the total number of employees, and the total production workers associated with the industry North American Industry Classification System (NAICS) code 333414, which covers consumer pool heater manufacturing.

Using the GRIM, DOE estimates that there would be 875 domestic production workers, and 505 non-production workers for consumer pool heaters in 2028 in the absence of new and amended energy conservation standards. Table 12.6.1 shows the range of the impacts of energy conservation standards on U.S. production on consumer pool heaters.

Table 12.6.1 Number of Domestic Consumer Pool Heater Workers in 2028

	No-New Standards Case	Trial Standard Level*					
		1	2	3	4	5	6
Domestic Production Workers in 2028	875	870	870	873	871	869	1,074
Domestic Non-Production Workers in 2028	505	502	502	504	503	501	620
Total Direct Employment in 2028	1,380	1,372	1,372	1,377	1,374	1,370	1,694
Potential Changes in Total Direct Employment in 2028	-	(32) – (8)	(32) – (8)	(32) – (3)	(32) – (6)	(32) – (10)	(371) – 314

*Numbers in parentheses indicate a negative number. Numbers may not sum exactly due to rounding.

The direct employment impacts shown in Table 12.6.1 represent the potential changes in direct employment that could result following the compliance date for consumer pool heaters. Employment could increase or decrease due to the labor content of the various products being manufactured domestically that meet the analyzed standards or if manufacturers decided to move production facilities abroad because of the new and amended standards. At one end of the range, DOE assumes that all manufacturers continue to manufacture the same scope of the products domestically after new and amended standards are required. However, since the labor content of consumer pool heaters varies by efficiency level, this can either result in an increase or decrease in domestic employment, even if all domestic product remains in the U.S. TSL 6 is estimated to have an increase in domestic employment, while TSL 1 through TSL 5, are estimated to have a reduction in domestic employment, assuming all production remains in the U.S.

The other end of the range assumes that some domestic manufacturing either is eliminated or moves abroad due to the analyzed new and amended standards. DOE assumes that for electric consumer pool heaters, only the electric resistance consumer pool heater employees would be impacted at all TSLs analyzed. DOE estimates there would be approximately 32 domestic production and non-production employees manufacturing electric resistance consumer pool heaters in 2028. Therefore, DOE assumes that for all TSLs analyzed, there would be a reduction in 32 domestic employees due to electric resistance consumer pool heaters no longer being manufactured domestically. For gas-fired consumer pool heaters, DOE assumes there would not be any impact to domestic production until TSL 6, max-tech. At this TSL, DOE assumes that up to half of all domestic gas-fired consumer pool heater production could move abroad due to the new and amended standards at TSL 6. TSL 6 would most likely require manufacturers of gas-fired consumer pool heaters to use condensing technology. Based on information from manufacturer interviews, this would require a significant investment to replace or re-tool existing production equipment. Some manufacturers of gas-fired consumer pool heaters could explore moving existing domestic production facilities abroad if most of the existing gas-fired consumer pool heater production equipment would need to be replaced or significantly re-tooled. DOE estimated there would be approximately 678 domestic production workers manufacturing gas-fired pool heaters in 2028. Therefore, DOE estimates that if standards were set at TSL 6, max-tech, there could be a loss of up to 371 domestic production employees responsible for manufacturing consumer pool heaters (339 domestic production employees manufacturing gas-fired consumer pool heaters and 32 domestic production and non-production employees manufacturing electric resistance consumer pool heaters).

12.6.2 Production Capacity

DOE identified potential manufacturing production capacity constraints at max-tech for both gas-fired consumer pool heaters and electric consumer pool heaters. There are 18 consumer pool heater manufacturers that manufacture electric consumer pool heaters covered by this rulemaking. Only three electric consumer pool heater manufacturers currently offer models that meet the efficiency level required at max-tech for electric consumer pool heaters and each of these three electric consumer pool heater manufacturers only offer a single model that meets the efficiency level required at max-tech for electric consumer pool heaters. All other electric consumer pool heater models offered by electric consumer pool heater manufacturers do not meet the efficiency level required at max-tech for electric pool heaters covered by this rulemaking.

There are six consumer pool heater manufacturers that manufacture gas-fired consumer pool heaters covered by this rulemaking. Only one gas-fired consumer pool heater manufacturer currently offers a model that meet the efficiency level required at max-tech for gas-fired pool heaters. All other gas-fired consumer pool heater models offered by gas-fired consumer pool heater manufacturers do not meet the efficiency level required at max-tech for gas-fired pool heaters covered by this rulemaking.

At max-tech (for both gas-fired consumer pool heaters and electric consumer pool heaters), most consumer pool heater manufacturers would therefore be required to redesign every consumer pool heater model covered by this rulemaking. It is unclear if most manufacturers would have the engineering capacity to complete the necessary redesigns (required to meet energy conservation standards at max-tech) within the 5-year compliance period. If some manufacturers require more than 5 years to redesign all their covered consumer pool heater models, they will likely prioritize redesigns based on sales volume. There is risk that some consumer pool heater models will become either temporarily or permanently unavailable after the compliance date.

DOE did not identify any significant manufacturing production capacity constraints for the design options below max-tech, that were being evaluated for this final rule. All gas-fired consumer pool heater manufacturers offer products that meet the EL below max-tech for gas-fired pool heaters, and more than half of the electric consumer pool heater manufacturers offer products that meet the EL below max-tech for electric consumer pool heaters. The design options below max-tech evaluated for this final rule are readily available as products that are on the market currently. The materials used to manufacture models at all ELs below max-tech are widely available on the market. As a result, DOE does not anticipate that the industry will likely experience any capacity constraints directly resulting from energy conservation standards at any of the ELs that are below max-tech.

12.6.3 Cumulative Regulatory Burden

One aspect of assessing manufacturer burden involves looking at the cumulative impact of multiple DOE standards and the regulatory actions of other Federal agencies and States that affect the manufacturers of a covered product or equipment. While any one regulation may not impose a significant burden on manufacturers, the combined effects of several existing or impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing products. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

DOE evaluates product-specific regulations that will take effect approximately 3 years before or after the estimated 2028 compliance date of any new and amended energy conservation standards for consumer pool heaters. This information is presented in Table 12.6.2.

Table 12.6.2 Compliance Dates and Expected Conversion Expenses of Federal Energy Conservation Standards Affecting Consumer Pool Heater Manufacturers

Federal Energy Conservation Standard	**Number of Mfrs***	**Number of Manufacturers Affected from Today's Rule****	**Approx. Standards Year**	**Industry Conversion Costs *(millions$)***	**Industry Conversion Costs / Product Revenue*****
Portable Air Conditioners 85 FR 1378 (Jan. 10, 2020)	11	2	2025	$320.9 (2015$)	6.7%
Room Air Conditioners‡	8	1	2026	$24.8 (2021$)	0.4%
Commercial Water Heating Equipment† 87 FR 30610 (May 19, 2022)	14	3	2026	$34.6 (2020$)	4.7%
Automatic Commercial Ice Makers†	23	1	2027	$15.9	0.6%
Consumer Furnaces (non-weatherized gas & mobile home)† 87 FR 40590 (July 7, 2022)	15	1	2029	$150.6 (2020$)	1.4%

* This column presents the total number of manufacturers identified in the energy conservation standard rule contributing to cumulative regulatory burden.
** This column presents the number of manufacturers producing consumer pool heaters that are also listed as manufacturers in the listed energy conservation standard contributing to cumulative regulatory burden.
*** This column presents industry conversion costs as a percentage of product revenue during the conversion period. Industry conversion costs are the upfront investments manufacturers must make to sell compliant products/equipment. The revenue used for this calculation is the revenue from just the covered product/equipment associated with each row. The conversion period is the time frame over which conversion costs are made and lasts from the publication year of the final rule to the compliance year of the energy conservation standard. The conversion period typically ranges from 3 to 5 years, depending on the rulemaking.
† Indicates a NOPR or SNOPR publication. Values may change on publication of a Final Rule.
‡ At the time of issuance of this consumer pool heaters rulemaking, the rulmaking has been issued and is pending publication in the Federal Register. Once published, the room air conditioners final rule will be available at: www.regulations.gov/docket/EERE-2014-BT-STD-0059.

In addition to the rulemakings listed in Table 12.6.2 DOE has ongoing rulemakings for other products or equipment that consumer pool heater manufacturers produce, including consumer furnaces (oil, electric, and weatherized gas);[1] consumer boilers;[2] consumer furnace fans;[3] consumer water heaters;[4] and dedicated-purpose pool pumps.[5] However, none of these rulemakings have published a NOPR or final rule to be able to estimate the size of the expected conversion costs manufacturers of these products or equipment must make.

12.7 CONCLUSION

This section summarizes the likely range of financial impacts consumer pool heater manufacturers will experience as a result of new and amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, circumstances could potentially cause manufacturers to experience impacts outside of this range.Table 12.7.1 and Table 12.7.2 summarize INPV impacts and conversion costs projected to result from each of the TSLs and Table 12.7.3 summarizes the cash flow impacts on manufacturers leading up to the compliance year.

Table 12.7.1 Manufacturer Impact Analysis Results: Preservation of Gross Margin Scenario

	Units	No-New-Standards Case	Trial Standard Level*					
			1	2	3	4	5	6
INPV	*2021$ millions*	585.7	585.2	584.5	577.0	575.0	587.7	631.6
Change in INPV	*2021$ millions*	-	(0.6)	(1.2)	(8.7)	(10.7)	2.0	45.9
	%	-	(0.1)	(0.2)	(1.5)	(1.8)	0.3	7.8
Product Conversion Costs	*2021$ millions*	-	1.3	2.6	9.1	20.0	34.0	88.0
Capital Conversion Costs	*2021$ millions*	-	-	0.8	9.5	9.5	14.5	38.5
Total Conversion Costs	*2021$ millions*	-	1.3	3.4	18.6	29.4	48.4	126.4

* Parentheses indicate negative values.

[1] www.regulations.gov/docket/EERE-2021-BT-STD-0031
[2] www.regulations.gov/docket/EERE-2019-BT-STD-0036
[3] www.regulations.gov/docket/EERE-2021-BT-STD-0029
[4] www.regulations.gov/docket/EERE-2017-BT-STD-0019
[5] www.regulations.gov/docket/EERE-2022-BT-STD-0001

Table 12.7.2 Manufacturer Impact Analysis Results: Preservation of Operating Profit Scenario

	Units	No-New-Standards Case	Trial Standard Level*					
			1	2	3	4	5	6
INPV	*2021$ millions*	585.7	583.6	581.9	570.8	563.0	548.4	482.7
Change in INPV	*2021$ millions*	-	(2.2)	(3.9)	(15.0)	(22.8)	(37.3)	(103.0)
	%	-	(0.4)	(0.7)	(2.6)	(3.9)	(6.4)	(17.6)
Product Conversion Costs	*2021$ millions*	-	1.3	2.6	9.1	20.0	34.0	88.0
Capital Conversion Costs	*2021$ millions*	-	-	0.8	9.5	9.5	14.5	38.5
Total Conversion Costs	*2021$ millions*	-	1.3	3.4	18.6	29.4	48.4	126.4

* Parentheses indicate negative values.

Table 12.7.3 Industry Free Cash Flow Impacts in the Year before Compliance (2027)

	Units	No-New-Standards-Case	Trial Standard Level*					
			1	2	3	4	5	6
Free Cash Flow (2027)	*2021$ millions*	51.0	50.5	49.7	43.5	39.6	32.4	2.4
Change in Free Cash Flow	*2021$ millions*	-	(0.5)	(1.3)	(7.5)	(11.4)	(18.6)	(48.6)
	%	-	(0.9)	(2.5)	(14.7)	(22.3)	(36.5)	(95.3)

* Parentheses indicate negative values.

At TSL 1, DOE estimates that impacts on INPV will range from $2.2 million to $0.6 million, or a change in INPV of 0.4 to 0.1 percent. At TSL 1, industry free cash-flow is $50.5 million, which is a decrease of approximately $0.5 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 1 would set the energy conservation standard for both gas-fired consumer pool heaters and electric consumer pool heaters at EL 1. DOE estimates that 96 percent of gas-fired consumer pool heater shipments and 92 percent of electric consumer pool heater shipments already meet or exceed the efficiency levels analyzed at TSL 1. Gas-fired consumer pool heater manufacturers would likely need to redesign any models with a standing pilot light. DOE assumed this would require approximately two months of engineering time per model, which would cost manufacturers approximately $0.1 million. Electric heat pump consumer pool heater manufacturers would incur approximately $1.2 million in product conversion costs primarily to test all compliant electric consumer pool heater models to demonstrate compliance with standards at TSL 1. DOE estimates consumer pool heater manufacturers will incur minimal to no capital conversion costs at TSL 1.

Furthermore, no electric resistance pool heaters meet or exceed the electric consumer pool heater efficiency level analyzed at TSL 1 or above. DOE estimates manufacturers will not incur conversion costs for electric resistance pool heaters, because of the expectation that these consumer pool heater products will be discontinued, as described in section IV.J.2.c of this document.

At TSL 1, the shipment-weighted average MPC for all consumer pool heaters increases by 0.5 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, manufacturers are able to fully pass on this slight cost increase to consumers. The slight increase in shipment-weighted average MPC for consumer pool heaters is slightly outweighed by the $1.3 million in conversion costs, causing a slightly negative change in INPV at TSL 1 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case, but manufacturers do not earn additional profit from their investments. In this scenario, the 0.5 percent shipment-weighted average MPC increase results in a reduction in the manufacturer margin after the compliance year. This reduction in the manufacturer margin and the $1.3 million in conversion costs incurred by manufacturers cause a slightly negative change in INPV at TSL 1 under the preservation of operating profit scenario.

At TSL 2, DOE estimates that impacts on INPV will range from $3.9 million to $1.2 million, or a change in INPV of 0.7 percent to 0.2 percent. At TSL 2, industry free cash-flow is $49.7 million, which is a decrease of approximately $1.3 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 2 would set the energy conservation standard at EL 1 for gas-fired consumer pool heaters and at EL 2 for electric consumer pool heaters. DOE estimates that 96 percent of gas-fired consumer pool heater shipments and 81 percent of electric consumer pool heater shipments already meet or exceed the efficiency levels analyzed at TSL 2. Gas-fired consumer pool heater manufacturers would likely need to redesign any models with a standing pilot light. DOE assumed this would cost manufacturers approximately $0.1 million. To bring non-compliant electric heat pump consumer pool heaters into compliance and to test all electric heat pump consumer pool heaters to demonstrate compliance with standards at TSL 2, electric heat pump consumer pool heater manufacturers would incur approximately $2.6 million in product conversion costs and $0.8 million in capital conversion costs at TSL 2.

At TSL 2, the shipment-weighted average MPC for all consumer pool heaters increases by 0.8 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, the slight increase in shipment-weighted average MPC for consumer pool heaters is slightly outweighed by the $3.4 million in conversion costs, causing a slightly negative change in INPV at TSL 2 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 0.8 percent shipment-weighted average MPC increase results in a reduction in the manufacturer margin after the compliance year. This reduction in the manufacturer margin and the $3.4 million in conversion costs incurred by manufacturers cause a slightly negative change in INPV at TSL 2 under the preservation of operating profit scenario.

At TSL 3, DOE estimates that impacts on INPV will range from -$15.0 million to $8.7 million, or a change in INPV of -2.6 percent to -1.5 percent. At TSL 3, industry free cash-flow is $43.5 million, which is a decrease of approximately $7.5 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 3 would set the energy conservation standard at EL 1 for gas-fired consumer pool heaters and at EL 3 for electric consumer pool heaters. DOE estimates that 96 percent of gas-fired consumer pool heater shipments and 22 percent of electric consumer pool heater shipments already meet or exceed the efficiency levels analyzed at TSL 3. Gas-fired consumer pool heater manufacturers would likely need to redesign any models with a standing pilot light. DOE assumed this would cost manufacturers approximately $0.1 million. To bring non-compliant electric heat pump consumer pool heaters into compliance and to test all electric heat pump consumer pool heaters to demonstrate compliance with standards at TSL 3, electric heat pump consumer pool heater manufacturers would incur approximately $9.0 million in product conversion costs and $9.5 million in capital conversion costs at TSL 3.

At TSL 3, the shipment-weighted average MPC for all consumer pool heaters increases by 1.9 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, the increase in shipment-weighted average MPC for consumer pool heaters is outweighed by the $18.6 million in conversion costs, causing a slightly negative change in INPV at TSL 3 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 1.9 percent shipment-weighted average MPC increase results in a reduction in the manufacturer margin after the compliance year. This reduction in the manufacturer margin and the $18.6 million in conversion costs incurred by manufacturers cause a slightly negative change in INPV at TSL 3 under the preservation of operating profit scenario.

At TSL 4, DOE estimates that impacts on INPV will range from -$22.8 million to $10.7 million, or a change in INPV of -3.9 percent to -1.8 percent. At TSL 4, industry free cash-flow is $39.6 million, which is a decrease of approximately $11.4 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 4 would set the energy conservation standard at EL 1 for gas-fired consumer pool heaters and at EL 4 for electric consumer pool heaters. DOE estimates that 96 percent of gas-fired consumer pool heaters and 12 percent of electric consumer pool heaters meet or exceed the efficiency levels analyzed at TSL 4. Gas-fired consumer pool heater manufacturers would likely need to redesign any models with a standing pilot light. DOE assumed this would cost manufacturers approximately $0.1 million. To bring non-compliant electric heat pump consumer pool heaters into compliance and to test all electric heat pump consumer pool heaters to demonstrate compliance with standards at TSL 4, electric heat pump consumer pool heater manufacturers would incur approximately $19.9 million in product conversion costs and $9.5 million in capital conversion costs at TSL 4.

At TSL 4, the shipment-weighted average MPC for all consumer pool heaters increases by 3.6 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, the increase in shipment-weighted average MPC for consumer pool heaters is outweighed by the $29.4 million in conversion costs, causing a slightly negative change in INPV at TSL 4 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 3.6 percent shipment-weighted average MPC increase results in a reduction in the manufacturer margin after the compliance year. This reduction in the manufacturer margin and the $29.4 million in conversion costs incurred by manufacturers causing a slightly negative change in INPV at TSL 4 under the preservation of operating profit scenario.

At TSL 5, DOE estimates that impacts on INPV will range from $37.3 million to $2.0 million, or a change in INPV of -6.4 percent to 0.3 percent. At TSL 5, industry free cash-flow is $32.4 million, which is a decrease of approximately $18.6 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 5 would set the energy conservation standard at EL 2 for gas-fired consumer pool heaters and at EL 4 for electric consumer pool heaters. DOE estimates that 50 percent of gas-fired consumer pool heaters and 12 percent of electric consumer pool heaters meet or exceed the efficiency levels analyzed at TSL 5. Gas-fired consumer pool heater manufacturers would likely need to incorporate a blower for gas-fired pool heaters. DOE assumed this would cost manufacturers approximately $14.1 million in product conversion costs and $5.0 million in capital conversion costs. To bring non-compliant electric heat pump consumer pool heaters into compliance and to test all electric heat pump consumer pool heaters to demonstrate compliance with standards at TSL 5, electric heat pump consumer pool heater manufacturers would incur approximately $19.9 million in product conversion costs and $9.5 million in capital conversion costs at TSL 5.

At TSL 5, the shipment-weighted average MPC for all consumer pool heaters increases by 10.0 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, the increase in shipment-weighted average MPC for consumer pool heaters outweighs the $48.4 million in conversion costs, causing a slightly positive change in INPV at TSL 5 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 10.0 percent shipment-weighted average MPC increase results in a reduction in the manufacturer margin after the compliance year. This reduction in manufacturer margin and the $48.4 million in conversion costs incurred by manufacturers cause a moderately negative change in INPV at TSL 5 under the preservation of operating profit scenario.

At TSL 6, DOE estimates that impacts on INPV will range from -$103.0 million to $45.9 million, or a change in INPV of -17.6 percent to 7.8 percent. At TSL 6, industry free cash-flow is $2.4 million, which is a decrease of approximately $48.6 million compared to the no-new-standards case value of $51.0 million in 2027, the year leading up to the adopted standards.

TSL 6 would set the energy conservation standard at EL 3 for gas-fired consumer pool heaters and at EL 5 for electric consumer pool heaters. This represents max-tech for both product classes. DOE estimates 9 percent of gas-fired consumer pool heaters and 3 percent of electric consumer pool heaters meet the efficiency levels analyzed at TSL 6. Gas-fired consumer pool heater manufacturers would likely need to incorporate condensing technology for all gas-fired pool heaters. DOE assumed this would cost manufacturers approximately $63.1 million in product conversion costs and $29.0 million in capital conversion costs. To bring non-compliant electric heat pump consumer pool heaters into compliance and to test all electric heat pump consumer pool heaters to demonstrate compliance with standards at TSL 6, electric heat pump consumer pool heater manufacturers would incur approximately $24.8 million in product conversion costs and $9.5 million in capital conversion costs at TSL 6.

At TSL 6, the shipment-weighted average MPC for all consumer pool heaters significantly increases by 37.0 percent relative to the no-new-standards case shipment-weighted average MPC for all consumer pool heaters in 2028. In the preservation of gross margin scenario, the large increase in shipment-weighted average MPC for consumer pool heaters outweighs the $126.4 million in conversion costs, causing a moderately positive change in INPV at TSL 6 under the preservation of gross margin scenario.

Under the preservation of operating profit scenario, the 37.0 percent shipment-weighted average MPC increase results in a significant reduction in the manufacturer margin after the compliance year. This large reduction in manufacturer margin and the significant $126.4 million in conversion costs incurred by manufacturers cause a moderately negative change in INPV at TSL 6 under the preservation of operating profit scenario.

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector emissions and, if present, site combustion emissions, of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg). The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the impacts to emissions of all species due to "upstream" activities in the fuel production chain, which are included in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011). These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion.

The analysis of power sector emissions of CO_2, NO_X, SO_2, and Hg uses emissions intensity factors intended to represent the marginal impacts of the change in electricity consumption associated with amended or new standards. The methodology is based on results published for the *Annual Energy Outlook (AEO)* prepared by the Energy Information Administration, including a set of side cases that implement a variety of efficiency-related policies. The methodology is described in appendix 13A to this TSD, and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin 2019).[1,2] The analysis presented in this chapter uses projections from the *AEO 2022*.[3]

Emissions of SO_2 and NO_X from site combustion of natural gas or petroleum fuels are calculated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[4] Power sector combustion emissions of CH_4 and N_2O are derived using Emission Factors for Greenhouse Gas Inventories published by the EPA, as are site combustion emissions of CO_2, CH_4 and N_2O.[a]

The FFC upstream emissions are estimated based on the methodology described in appendix 10B and in Coughlin (2013).[5] The upstream emissions include emissions from fuel combustion during extraction, processing, and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated by multiplying the emissions intensity factor by the energy savings calculated in the national impact analysis (chapter 10). The emissions factors used in the calculations are provided in appendix 13A. For power sector emissions, the factors depend on the sector and end use. The results presented here use factors for the power plant types that supply electricity for pool heaters in homes and commercial buildings.

Each annual version of the *AEO* incorporates the projected impacts of existing air quality regulations on emissions. The *AEO* generally represents current Federal and State legislation and

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[a] https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf.

final implementation regulations in place as at the time of its preparation. For details, see Summary of Legislation and Regulations Included in the *AEO 2022*, Appendix, Electric power sector.[b]

13.2 EMISSIONS IMPACT RESULTS

Table 13.2.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2028-2057 for each TSL. Negative values indicate that emissions increase.

Table 13.2.1 Cumulative Emissions Reduction for Potential Standards for Pool Heaters

	TSL					
	1	**2**	**3**	**4**	**5**	**6**
Power Sector and Site Emissions						
CO_2 (million metric tons)	7.9	9.6	12.7	13.9	26.1	138.1
SO_2 (thousand tons)	0.5	0.7	0.9	1.0	1.2	3.7
NO_X (thousand tons)	0.1	0.1	0.1	0.1	0.2	0.4
Hg (tons)	13.0	13.8	15.4	16.0	198.0	217.5
CH_4 (thousand tons)	3.2	3.9	5.4	5.9	5.9	7.4
N_2O (thousand tons)	0.02	0.03	0.03	0.04	0.04	0.04
Upstream Emissions						
CO_2 (million metric tons)	0.7	0.8	1.1	1.2	2.8	17.4
SO_2 (thousand tons)	65.9	78.3	101.3	110.4	283.1	1836.5
NO_X (thousand tons)	0.003	0.004	0.005	0.01	0.01	0.03
Hg (tons)	10.4	12.4	16.0	17.5	42.8	271.0
CH_4 (thousand tons)	0.04	0.05	0.1	0.1	0.1	0.2
N_2O (thousand tons)	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002
Total Emissions						
CO_2 (million metric tons)	8.6	10.4	13.7	15.0	28.9	155.5
SO_2 (thousand tons)	66.4	78.9	102.2	111.4	284.4	1840.2
NO_X (thousand tons)	0.1	0.1	0.1	0.1	0.2	0.4
Hg (tons)	23.4	26.2	31.4	33.5	240.8	488.5
CH_4 (thousand tons)	3.2	4.0	5.4	6.0	6.0	7.6
N_2O (thousand tons)	0.02	0.03	0.03	0.04	0.04	0.04

Figure 13.2.1 through Figure 13.2.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold in 2028-2057.

[b] https://www.eia.gov/outlooks/aeo/assumptions/pdf/summary.pdf

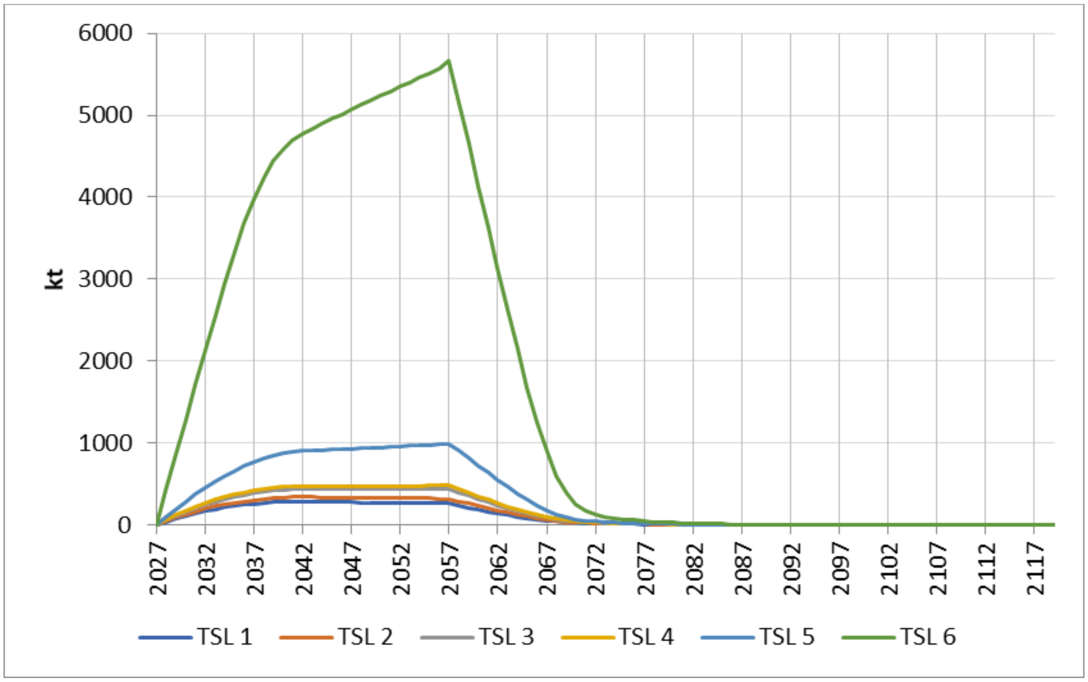

Figure 13.2.1 Pool Heaters: CO_2 Total Emissions Reduction

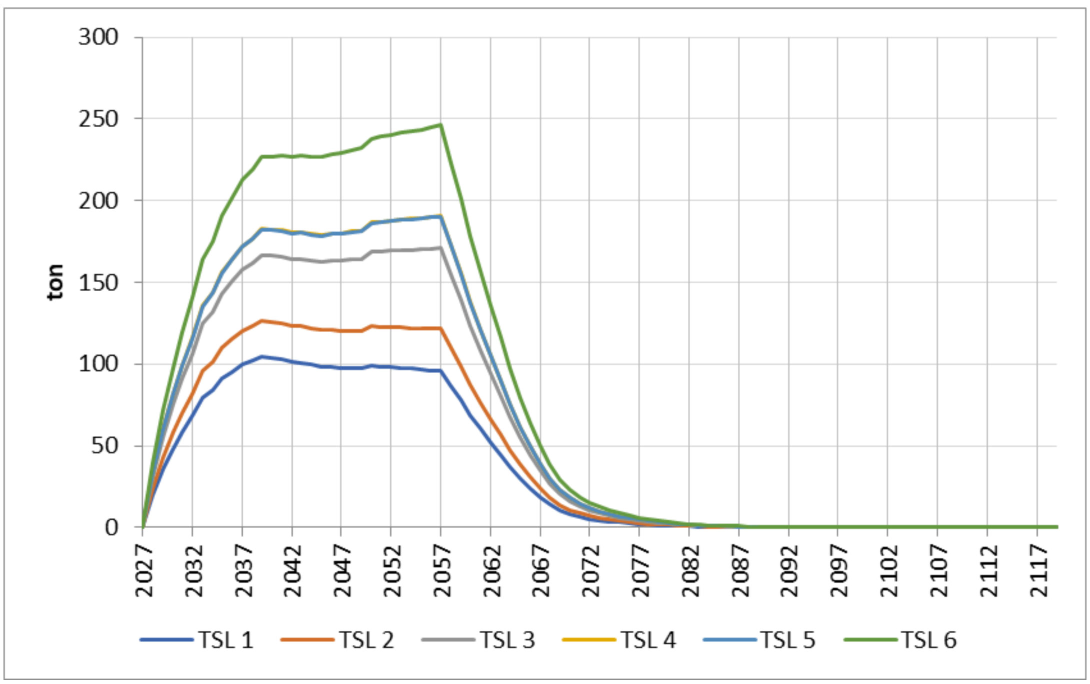

Figure 13.2.2 Pool Heaters: SO_2 Total Emissions Reduction

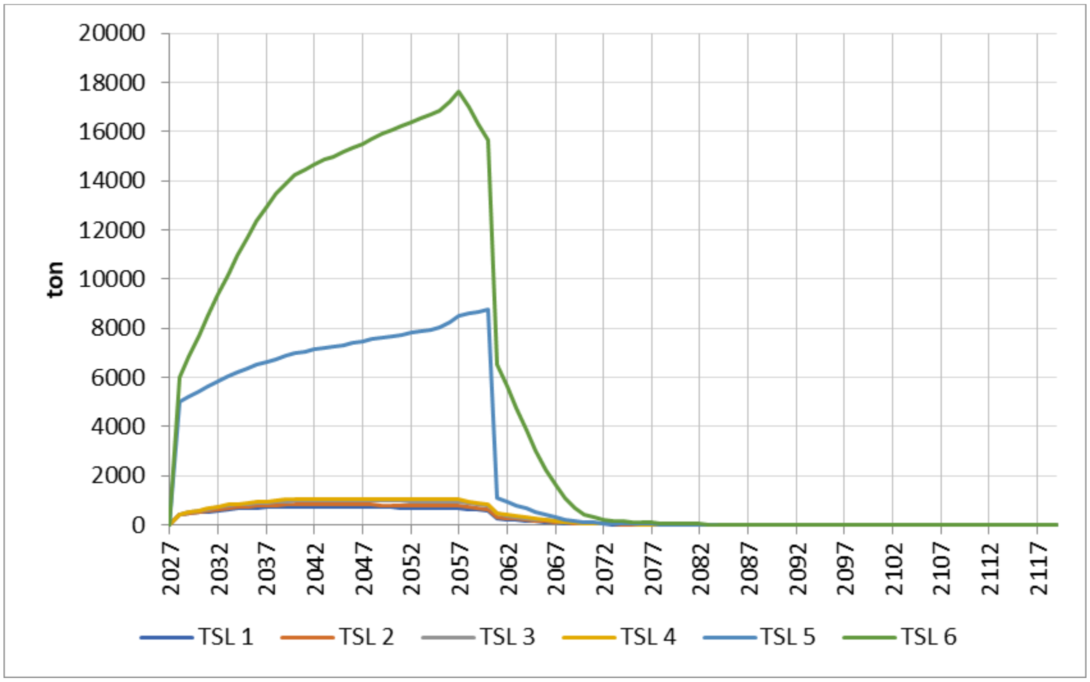

Figure 13.2.3 Pool Heaters: NO_x Total Emissions Reduction

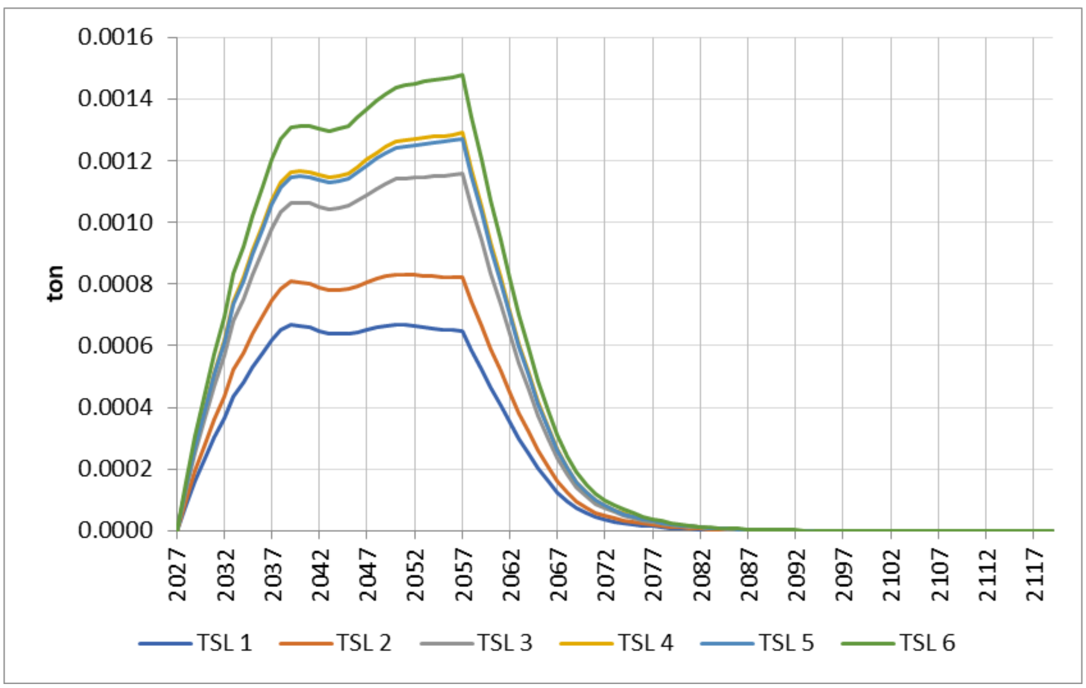

Figure 13.2.4 Pool Heaters: Hg Total Emissions Reduction

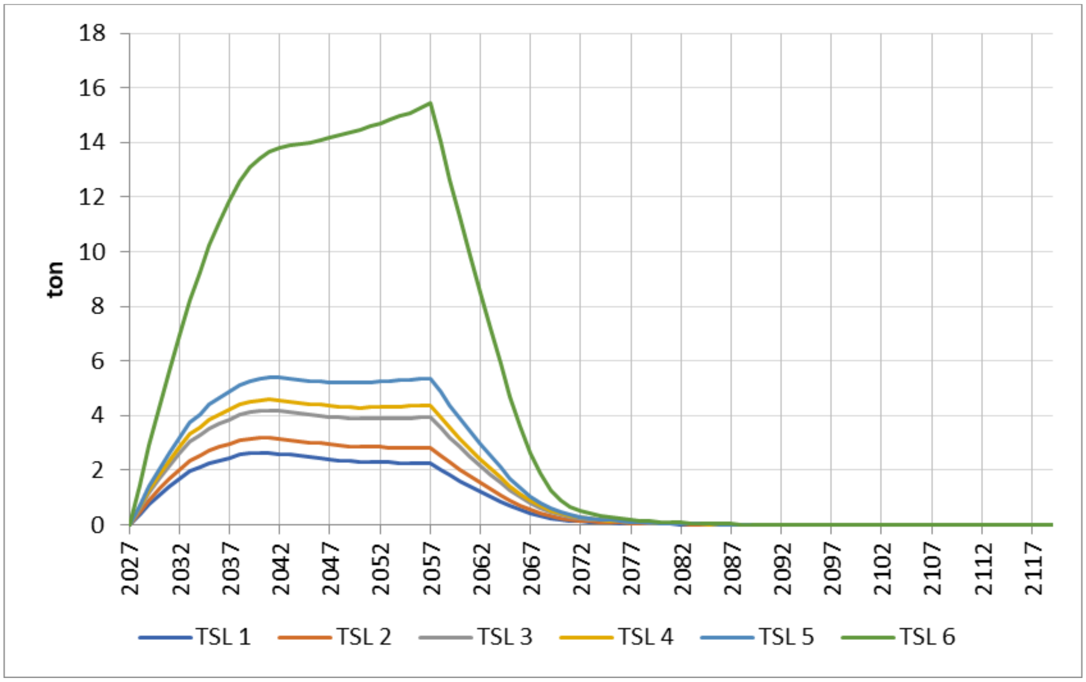

Figure 13.2.5 Pool Heaters: N_2O Total Emissions Reduction

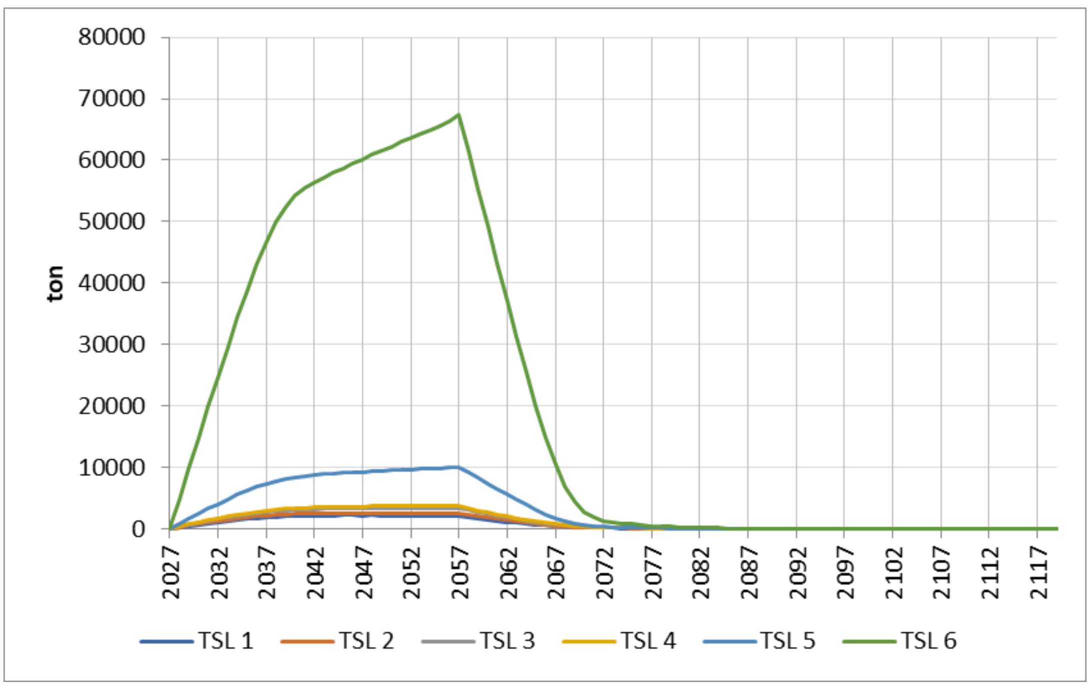

Figure 13.2.6 Pool Heaters: CH_4 Total Emissions Reduction

Table 13.2.2 below displays annual emissions reductions at the proposed level (TSL 5) in the NOPR.

Table 13.2.2 Estimated Emissions Reduction at Proposed Standard Level (TSL 5)

Emissions Year	CO_2 (million metric tons)	CH_4 (thousand tons)	N_2O (thousand tons)	NO_X (thousand tons)	SO_2 (thousand tons)	Hg (tons)
2028	0.097	0.84	0.0007	4.99	0.033	0.00014
2029	0.190	1.66	0.0014	5.21	0.060	0.00027
2030	0.280	2.47	0.0020	5.42	0.081	0.00039
2031	0.367	3.26	0.0026	5.63	0.099	0.00050
2032	0.451	4.05	0.0032	5.83	0.115	0.00061
2033	0.533	4.82	0.0037	6.03	0.135	0.00073
2034	0.600	5.52	0.0041	6.20	0.143	0.00081
2035	0.663	6.17	0.0044	6.35	0.156	0.00090
2036	0.719	6.78	0.0046	6.49	0.164	0.00098
2037	0.770	7.32	0.0049	6.62	0.172	0.00106
2038	0.815	7.79	0.0051	6.75	0.176	0.00111
2039	0.848	8.14	0.0053	6.87	0.182	0.00115
2040	0.871	8.41	0.0053	6.97	0.182	0.00115
2041	0.888	8.62	0.0054	7.05	0.181	0.00115
2042	0.900	8.77	0.0054	7.12	0.180	0.00114
2043	0.906	8.88	0.0054	7.20	0.180	0.00113
2044	0.913	8.99	0.0053	7.26	0.179	0.00113
2045	0.918	9.09	0.0053	7.32	0.179	0.00114
2046	0.924	9.19	0.0053	7.40	0.179	0.00116
2047	0.928	9.27	0.0052	7.47	0.180	0.00118
2048	0.934	9.37	0.0052	7.54	0.181	0.00121
2049	0.939	9.45	0.0052	7.61	0.182	0.00123
2050	0.944	9.51	0.0052	7.67	0.186	0.00124
2051	0.950	9.59	0.0052	7.74	0.187	0.00125
2052	0.957	9.66	0.0052	7.81	0.187	0.00125
2053	0.963	9.73	0.0053	7.87	0.188	0.00125
2054	0.969	9.80	0.0053	7.94	0.189	0.00126
2055	0.975	9.87	0.0053	8.01	0.189	0.00126
2056	0.982	9.96	0.0053	8.26	0.190	0.00126
2057	0.992	10.06	0.0054	8.52	0.190	0.00127
2058	0.901	9.15	0.0049	8.60	0.172	0.00115
2059	0.811	8.24	0.0044	8.68	0.155	0.00103
2060	0.722	7.33	0.0039	8.76	0.138	0.00092
2061	0.634	6.44	0.0034	1.09	0.121	0.00081
2062	0.547	5.55	0.0030	0.94	0.105	0.00070
2063	0.463	4.69	0.0025	0.80	0.090	0.00060
2064	0.382	3.86	0.0021	0.66	0.075	0.00050

Emissions Year	CO_2 (million metric tons)	CH_4 (thousand tons)	N_2O (thousand tons)	NO_X (thousand tons)	SO_2 (thousand tons)	Hg (tons)
2065	0.306	3.07	0.0017	0.52	0.062	0.00041
2066	0.236	2.35	0.0014	0.40	0.049	0.00033
2067	0.176	1.72	0.0010	0.30	0.039	0.00026
2068	0.126	1.22	0.0008	0.21	0.030	0.00020
2069	0.090	0.84	0.0006	0.15	0.023	0.00016
2070	0.065	0.59	0.0005	0.11	0.018	0.00012
2071	0.049	0.43	0.0004	0.08	0.015	0.00010
2072	0.038	0.34	0.0003	0.06	0.012	0.00008
2073	0.031	0.28	0.0002	0.05	0.010	0.00007
2074	0.026	0.23	0.0002	0.04	0.008	0.00006
2075	0.022	0.19	0.0002	0.04	0.007	0.00005
2076	0.018	0.16	0.0001	0.03	0.006	0.00004
2077	0.015	0.13	0.0001	0.02	0.005	0.00003
2078	0.012	0.11	0.0001	0.02	0.004	0.00003
2079	0.010	0.09	0.0001	0.02	0.003	0.00002
2080	0.008	0.07	0.0001	0.01	0.003	0.00002
2081	0.006	0.06	0.0000	0.01	0.002	0.00001
2082	0.005	0.05	0.0000	0.01	0.002	0.00001
2083	0.004	0.04	0.0000	0.01	0.001	0.00001
2084	0.003	0.03	0.0000	0.01	0.001	0.00001
2085	0.003	0.02	0.0000	0.00	0.001	0.00001
2086	0.002	0.02	0.0000	0.00	0.001	0.00000
2087	0.002	0.02	0.0000	0.00	0.001	0.00000
2088	0.001	0.01	0.0000	0.00	0.000	0.00000
2089	0.001	0.01	0.0000	0.00	0.000	0.00000
2090	0.001	0.01	0.0000	0.00	0.000	0.00000
2091	0.001	0.01	0.0000	0.00	0.000	0.00000
2092	0.001	0.00	0.0000	0.00	0.000	0.00000
2093	0.000	0.00	0.0000	0.00	0.000	0.00000
2094	0.000	0.00	0.0000	0.00	0.000	0.00000
2095	0.000	0.00	0.0000	0.00	0.000	0.00000
Cumulative	28.9	284	0.17	241	6.0	0.04

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CHAPTER 14. MONETIZATION OF EMISSIONS REDUCTION BENEFITS

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14.1 INTRODUCTION

As part of its assessment of energy conservation standards for pool heaters, the U.S. Department of Energy (DOE) considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2) and nitrogen oxides (NO_X) that are expected to result from each of the potential standard levels considered. This chapter summarizes the basis for the benefit-per-ton values used for each of these emissions and presents the estimated total benefits for each TSL.

To monetize the benefits of reducing GHG emissions this analysis uses the interim estimates presented in the *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990* published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG).

14.2 MONETIZING AVOIDED GREENHOUSE GAS EMISSIONS

DOE estimates the monetized benefits of the reductions in greenhouse gas (GHG) emissions of CO_2, CH_4, and N_2O by using a measure of the social cost (SC) of each pollutant (*e.g.*, SC- CO_2). These estimates represent the monetary value of the net harm to society associated with a marginal increase in emissions of these pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. DOE exercises its own judgment in presenting monetized climate benefits as recommended by applicable Executive Orders, and DOE would reach the same conclusion presented in this document in the absence of the social cost of greenhouse gases, including the February 2021 Interim Estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

DOE estimated the global social benefits of CO_2, CH_4, and N_2O reductions (*i.e.,* SC-GHGs) using the estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG).[1] The SC-GHGs is the monetary value of the net harm to society associated with a marginal increase in emissions in a given year, or the benefit of avoiding that increase. In principle, SC-GHGs includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHGs therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton. The SC-GHGs is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CO_2, N_2O, and CH_4 emissions. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD), the DOE agrees that the interim SC-GHG estimates represent the most appropriate estimate of the SC-GHG until revised estimates have been developed reflecting the latest, peer-reviewed science.

The SC-GHGs estimates presented here were developed over many years, using transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an interagency working group (IWG) that included the DOE and other executive branch agencies and offices was established to ensure that agencies were using the best available science and to promote consistency in the social cost of carbon (SC-CO_2) values used across agencies. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate global climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS) – a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM. In August 2016 the IWG published estimates of the social cost of methane (SC-CH_4) and nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten et al. (2015) and underwent a standard double-blind peer review process prior to journal publication.[2]

In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process.[3] Shortly thereafter, in March 2017, President Trump issued Executive Order 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure SC-CO_2 estimates used in regulatory analyses are consistent with the guidance contained in OMB's Circular A-4, "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)). Benefit-cost analyses following E.O. 13783 used SC-GHG estimates that attempted to focus on the U.S.-specific share of climate change damages as estimated by the models and were calculated using two discount rates recommended by Circular A-4, 3 percent and 7 percent. All other methodological decisions and model versions used in SC-GHG calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

On January 20, 2021, President Biden issued Executive Order 13990, which re-established the IWG and directed it to ensure that the U.S. Government's estimates of the social cost of carbon and other greenhouse gases reflect the best available science and the recommendations of the National Academies (2017). The IWG was tasked with first reviewing the SC-GHG estimates currently used in Federal analyses and publishing interim estimates within 30 days of the EO that reflect the full impact of GHG emissions, including by taking global damages into account. The interim SC-GHG estimates published in February 2021, specifically the SC-CH_4 estimates, are used here to estimate the climate benefits for this rulemaking. The EO instructs the IWG to update the SC-GHG estimates by January 2022, taking into consideration the advice of the National Academies of Science, Engineering, and Medicine as reported in *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide* (2017) and other recent scientific literature.

The February 2021 SC-GHG TSD provides a complete discussion of the IWG's initial review conducted under EO 13990. In particular, the IWG found that the SC-GHG estimates used under EO 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG found that the SC-GHG estimates used under E.O. 13783 fail to fully capture many climate impacts that affect the welfare of U.S. citizens and residents, and those impacts are better reflected by global measures of the SC-GHG. Examples of omitted effects from the EO 13783 estimates include direct effects on U.S. citizens, assets, and investments located abroad, supply chains, U.S. military assets and interests abroad, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concern. In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. If the United States does not consider impacts on other countries, it is difficult to convince other countries to consider the impacts of their emissions on the United States. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—is for all countries to base their policies on global estimates of damages. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees with this assessment and, therefore, in this proposed rule DOE centers attention on a global measure of SC-GHG. This approach is the same as that taken in DOE regulatory analyses from 2012 through 2016. A robust estimate of climate damages that accrue only to U.S. citizens and residents does not currently exist in the literature. As explained in the February 2021 TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the U.S. because they do not fully capture the regional interactions and spillovers discussed above, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature. As noted in the February 2021 SC–GHG TSD, the IWG will continue to review developments in the literature, including more robust methodologies for estimating a U.S.-specific SC–GHG value, and explore ways to better inform the public of the full range of carbon impacts. As a member of the IWG, DOE will continue to follow developments in the literature pertaining to this issue.

Second, the IWG found that the use of the social rate of return on capital (7 percent under current OMB Circular A-4 guidance) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-GHG. Consistent with the findings of the National Academies (2017) and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context (IWG 2010, 2013, 2016a, 2016b), and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[4,5,6,7] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4's guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. DOE also notes that while OMB Circular A-4, as published in 2003, recommends using 3% and 7% discount rates as "default" values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions." On discounting, Circular A-4 recognizes that "special ethical considerations arise when comparing benefits and costs across generations," and Circular A-4 acknowledges that analyses may appropriately "discount future costs and consumption benefits…at a lower rate than for intragenerational analysis." In the 2015 Response to Comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, DOE, and the other IWG members recognized that "Circular A-4 is a living document" and "the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." Thus, DOE concludes that a 7% discount rate is not appropriate to apply to value the social cost of greenhouse gases in the analysis presented in this analysis. In this analysis, to calculate the present and annualized values of climate benefits, DOE uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 TSD recommends "to ensure internal consistency—*i.e.,* future damages from climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5 percent rate." DOE has also consulted the National Academies' 2017 recommendations on how SC-GHG estimates can "be combined in RIAs with other cost and benefits estimates that may use different discount rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue.

While the IWG works to assess how best to incorporate the latest, peer reviewed science to develop an updated set of SC-GHG estimates, it set the interim estimates to be the most recent estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 SC-GHG TSD, the IWG has recommended that agencies revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values recommended for use in benefit-cost analyses: an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3 percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change. As explained in the February 2021 SC-GHG TSD, and DOE agrees, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

There are a number of limitations and uncertainties associated with the SC-GHG estimates. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower.[1] Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" – *i.e.,* the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages – lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections. The modeling limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates. However, as discussed in the February 2021 TSD, the IWG has recommended that, taken together, the limitations suggest that the interim SC-GHG estimates used in this final rule likely underestimate the damages from GHG emissions. DOE concurs with this assessment.

DOE's derivations of the SC-GHGs (*i.e.,* SC-CO_2, SC-N_2O, and SC-CH_4) values are discussed in the following sections.

14.2.1 Social Cost of Carbon

The SC-CO_2 values used for DOE's analysis were generated using the values presented in the 2021 update from the IWG. Table 14.2.1 shows the four sets of SCC estimates in five-year increments from 2020 to 2070.[a] DOE expects additional climate benefits to accrue for any longer-life pool heaters, but a lack of available SC-CO_2 estimates for emissions years beyond 2070 prevents DOE from monetizing these additional benefits in this analysis. The case labeled "95th percentile" refers to values in the 95th percentile of simulations. Appendix 14A provides the full set of SCC estimates. For purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SCC values.

[a] The values for the years after 2050 are based on modeling conducted by EPA for the "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis" published by EPA in December 2021. See Appendix 14A.

Table 14.2.1 Annual SC-CO_2 Values Based on 2021 Interagency Update and 2021 EPA Analysis, 2020–2070 (2020 dollars per metric ton)*

Year	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2020	14	51	76	151
2025	17	56	83	169
2030	19	62	89	186
2035	22	67	96	205
2040	25	73	103	224
2045	28	79	109	242
2050	32	84	116	259
2055	35	89	122	265
2060	38	93	128	275
2065	44	100	135	300
2070	49	108	143	326

* For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SC-CO_2 value for that year in each of the four cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the specific discount rate that had been used to obtain the SC-CO_2 values in each case.

14.2.2 Social Cost of Methane and Nitrous Oxide

The SC-CH_4 and SC- N_2O values used for the present analysis were generated using the values presented in the 2021 update from the IWG. Table 14.2.2 shows the four sets of SC-CH_4 and SC- N_2O estimates from the latest interagency update in 5-year increments from 2020 to 2070. For purposes of capturing the uncertainties involved in regulatory impact analysis, the interagency group emphasizes the importance of including all four sets of SC-CH_4 and SC- N_2O values. The full set of annual values is reported in appendix 14A of the NOPR TSD.

DOE multiplied the CH_4 and N_2O emissions reduction estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the cases. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the cases using the specific discount rate that had been used to obtain the SC-CH_4 and SC-N_2O estimates in each case.

Table 14.2.2 Annual SC-CH_4 and SC-N_2O Values Based on 2021 Interagency Update and 2021 EPA Analysis, 2020–2070 (2020$ per metric ton)*

Year	SC-CH_4				SC-N_2O			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5%	3%	2.5%	3%	5%	3%	2.5 %	3%
	Average	Average	Average	95th percentile	Average	Average	Average	95th percentile
2020	663	1,480	1,946	3,893	5,760	18,342	27,037	48,090
2025	799	1,714	2,223	4,533	6,766	20,520	29,811	54,108
2030	935	1,948	2,499	5,173	7,772	22,698	32,585	60,125
2035	1,106	2,224	2,817	5,939	9,007	25,149	35,632	66,898
2040	1,277	2,500	3,136	6,705	10,241	27,600	38,678	73,670
2045	1,464	2,778	3,450	7,426	11,687	30,238	41,888	80,766
2050	1,651	3,057	3,763	8,147	13,133	32,875	45,098	87,863
2055	1,772	3,221	3,942	8,332	14,758	35,539	48,236	94,117
2060	1,899	3,395	4,130	8,539	16,424	38,300	51,507	100,845
2065	2,508	4,163	4,960	11,177	19,687	42,625	56,397	115,590
2070	3,130	4,976	5,867	14,079	23,018	47,072	61,428	130,928

* For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

14.3 VALUATION OF NO_X AND SO_2 EMISSIONS REDUCTIONS

As noted in chapter 13, new or amended energy conservation standards would reduce SO_2 emissions from electricity generation, and NO_X emissions in those States that are not affected by caps. For each of the considered TSLs, DOE estimated monetized values of NO_X and SO_2 emissions reductions from electricity generation using the latest benefit-per-ton estimates for that sector from the EPA's Benefits Mapping and Analysis Program.[b] DOE used EPA's values for $PM_{2.5}$-related benefits associated with NO_X and SO_2 and for ozone-related benefits associated with NO_X for 2025, 2030, 2035 and 2040, calculated with discount rates of 3 percent and 7 percent. DOE used linear interpolation to define values for the years not given in the 2025 to 2040 period; for years beyond 2040 the values are held constant.

The ozone-related benefits associated with NO_X occur only in the ozone-season (May to September). EPA data indicate that ozone-season NO_X emissions from electricity generation are slightly less than half of all-year NO_X emissions. DOE accounted for this characteristic in its methodology.

DOE combined the EPA data with data from *AEO2022* to estimate benefit-per-ton values by sector. Appendix 14B provides methodological details and values that DOE used. The results presented in this chapter use benefit-per-ton values for the residential and commercial sectors. DOE multiplied the emissions reduction (in tons) in each year by the associated $/ton values, and then discounted each series using discount rates of 3 percent and 7 percent as appropriate.

[b] *Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 21 Sectors*. https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors

The considered standards for pool heaters also reduce NOx and SO_2 emissions from combustion at the home or commercial building. To monetize the value of these emissions reductions, DOE used benefit-per-ton estimates from the Benefits Mapping and Analysis Program's 2018 report Technical Support Document Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors.[8] Although none of the sectors refers specifically to residential and commercial buildings, the sector called "Area sources" would be a reasonable proxy for residential and commercial buildings. "Area sources" represents all emission sources for which states do not have exact (point) locations in their emissions inventories. Because exact locations would tend to be associated with larger sources, "area sources" would be fairly representative of small dispersed sources like homes and businesses.[c]

The EPA document provides high and low estimates for 2025 and 2030 at 3 and 7 percent discount rates (see table below). DOE converted the values to 2020$, and interpolated and extrapolated values as described above.

Table 14.3.1 Summary of the Total Dollar Value per Ton of Directly Emitted $PM_{2.5}$ Precursor Reduced from Area Sources (2015$)

Year of Emission	Low		High	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
	NO_X			
2025	9,700	8,800	22,000	20,000
2030	11,000	9,500	24,000	21,000
	SO_2			
2025	61,000	55,000	140,000	120,000
2030	67,000	60,000	150,000	140,000

[c] The sector "Area sources" was not used in the EPA's most recent analysis that DOE used for the electricity generation sector.

14.4 RESULTS

14.4.1 Benefits for Considered TSLs

The tables in this section show the emissions monetization results for each considered TSL.

Table 14.4.1 Present Social Value of CO_2 Emissions Reduction for Potential Standards for Pool Heaters

TSL	SC-CO_2 Case			
	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th percentile
	million 2020$			
1	79	342	537	1,041
2	95	412	645	1,251
3	124	540	847	1,639
4	136	591	927	1,794
5	259	1,133	1,781	3,440
6	1,381	6,079	9,569	18,455

Table 14.4.2 Present Social Value of Methane Emissions Reduction for Potential Standards for Pool Heaters

TSL	SC-CH_4 Case			
	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
	million 2020$			
1	28	84	117	222
2	33	99	139	263
3	42	128	179	339
4	46	140	195	369
5	117	357	500	943
6	758	2,312	3,243	6,109

Table 14.4.3 Present Social Value of Nitrous Oxide Emissions Reduction for Potential Standards for Pool Heaters

TSL	SC-N_2O Case			
	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
	million 2020$			
1	0.3	1.1	1.7	2.9
2	0.3	1.3	2.1	3.6
3	0.4	1.8	2.8	4.8
4	0.5	2.0	3.1	5.3
5	0.6	2.4	3.7	6.3
6	1.5	6.2	9.6	16.4

Table 14.4.4 Present Monetized Social Value of SO_2 Emissions Reduction for Potential Standards for Pool Heaters

TSL	7% discount rate	3% discount rate
	billion 2020$	
1	70	172
2	85	211
3	113	285
4	125	314
5	124	312
6	151	383

Table 14.4.5 Present Monetized Social Value of NO_X Emissions Reduction for Potential Standards for Pool Heaters

TSL	7% discount rate	3% discount rate
	billion 2020$	
1	216	546
2	257	653
3	331	849
4	360	927
5	741	1,939
6	4,192	11,117

14.4.2 Annual and Cumulative Benefits for Selected Standards (TSL 5)

The tables in this section present climate and health benefits estimated for the selected standards. The benefits of reduced CO_2, CH_4, and N_2O emissions are collectively referred to as climate benefits. The benefits of reduced SO_2 and NO_X emissions are collectively referred to as health benefits.

The annual values reflect the benefits from reduced emissions in each year. The associated benefits accrue over very many years in the case of GHG emissions, and over several years in the case of NOx and SO_2 emissions. The time stream of benefits has been discounted to estimate the benefit-per-ton values for each year, but the total benefits associated with each emissions year are not discounted in these tables. The cumulative present value does reflect discounting at the noted discount rates.

Table 14.4.6 Climate Benefits from GHG Emissions Reduction (CO_2, CH_4, and N_2O) at Proposed Standard Level (TSL 5)

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2030	7.8	22.6	32.0	66.6
2035	21.9	59.7	83.2	177.2
2040	33.1	86.5	118.8	258.0
2045	39.9	99.6	134.9	296.2
2050	46.1	110.9	148.6	329.4
2055	52.1	120.6	161.5	348.6
2060	41.8	94.2	125.2	267.4
2065	21.2	44.2	57.7	128.6
2070	5.1	10.1	13.0	29.9
Cumulative PV	377	1492	2285	4390
Annualized	31	88	124	260

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5, 3, 2.5 percent) is used to calculate the present value of SC-GHGs for internal consistency. Annual benefits shown are undiscounted values.

Table 14.4.7 Estimated Climate Benefits from Changes in CO_2 Emissions at Proposed Standard Level (TSL 5)

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2028	1.9	6.0	8.8	18.2
2029	3.7	12.0	17.5	36.3
2030	5.6	18.0	26.1	54.4
2031	7.6	24.1	34.8	72.9
2032	9.7	30.1	43.3	91.4

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2033	11.7	36.2	51.9	110.0
2034	13.6	41.4	59.3	126.2
2035	15.4	46.6	66.5	142.2
2036	17.1	51.4	73.1	157.0
2037	18.8	55.9	79.4	171.2
2038	20.4	60.2	85.2	184.4
2039	21.8	63.7	89.9	195.4
2040	22.9	66.4	93.6	204.1
2041	23.9	68.8	96.7	211.4
2042	24.8	70.8	99.1	217.4
2043	25.6	72.3	101.1	222.2
2044	26.4	73.9	103.1	227.1
2045	27.2	75.5	105.0	231.8
2046	28.0	77.0	106.9	236.6
2047	28.7	78.5	108.7	241.2
2048	29.5	80.1	110.7	246.0
2049	30.3	81.7	112.6	250.7
2050	31.1	83.2	114.5	255.5
2051	32.2	84.3	116.9	258.1
2052	33.0	85.8	118.8	260.7
2053	33.8	87.3	120.6	263.3
2054	34.6	88.8	122.5	265.8
2055	35.4	90.3	124.3	270.1
2056	36.3	92.0	126.5	274.4
2057	37.3	93.9	128.8	279.1
2058	34.5	86.2	118.1	255.5
2059	31.5	78.4	107.2	231.6
2060	28.5	70.5	96.3	207.6
2061	25.8	62.8	85.5	185.6
2062	22.9	55.0	74.7	163.1
2063	20.0	47.2	64.0	140.4
2064	16.9	39.5	53.4	117.8
2065	13.9	32.1	43.2	95.9
2066	11.0	25.1	33.7	75.3
2067	8.4	18.9	25.4	57.0
2068	6.2	13.8	18.5	41.7
2069	4.5	9.9	13.3	30.1
2070	3.3	7.2	9.6	22.0
Cumulative PV	259	1133	1781	3440

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
Annualized	21	67	96	203

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5, 3, 2.5 percent) is used to calculate the present value of SC-GHGs for internal consistency. Annual benefits shown are undiscounted values.

Table 14.4.8 Estimated Climate Benefits from Changes in CH_4 Emissions at Proposed Standard Level (TSL 5)

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2028	0.7	1.5	1.9	3.9
2029	1.4	3.0	3.8	7.9
2030	2.2	4.6	5.8	12.1
2031	3.0	6.2	7.9	16.5
2032	3.9	7.9	10.1	21.0
2033	4.7	9.6	12.3	25.7
2034	5.6	11.4	14.4	30.3
2035	6.5	13.0	16.5	34.7
2036	7.3	14.6	18.5	39.1
2037	8.2	16.2	20.5	43.4
2038	8.9	17.6	22.2	47.2
2039	9.6	18.9	23.7	50.6
2040	10.2	19.9	25.0	53.5
2041	10.7	20.9	26.1	55.9
2042	11.2	21.7	27.1	58.1
2043	11.7	22.5	28.0	60.1
2044	12.2	23.2	28.9	62.1
2045	12.6	23.9	29.7	64.0
2046	13.1	24.7	30.6	65.9
2047	13.5	25.4	31.4	67.8
2048	14.0	26.2	32.3	69.8
2049	14.5	26.9	33.1	71.7
2050	14.9	27.6	33.9	73.5
2051	15.3	28.1	34.6	74.5
2052	15.6	28.6	35.2	75.4
2053	15.9	29.1	35.7	76.2
2054	16.3	29.6	36.3	77.1
2055	16.6	30.1	36.9	78.0

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2056	17.0	30.7	37.6	79.0
2057	17.4	31.4	38.3	80.3
2058	16.0	28.9	35.2	73.4
2059	14.6	26.2	32.0	66.4
2060	13.2	23.6	28.7	59.4
2061	12.3	21.7	26.2	55.3
2062	11.3	19.5	23.5	50.5
2063	10.1	17.1	20.6	45.0
2064	8.7	14.7	17.5	38.9
2065	7.3	12.1	14.4	32.5
2066	5.9	9.6	11.4	26.2
2067	4.5	7.3	8.7	20.2
2068	3.3	5.4	6.4	14.9
2069	2.4	3.8	4.5	10.8
2070	1.8	2.8	3.3	7.9
Cumulative PV	117	357	500	943
Annualized	10	21	27	56

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5, 3, 2.5 percent) is used to calculate the present value of SC-GHGs for internal consistency. Annual benefits shown are undiscounted values.

Table 14.4.9 Estimated Climate Benefits from Changes in N_2O Emissions at Proposed Standard Level (TSL 5)

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2028	0.005	0.015	0.022	0.040
2029	0.010	0.029	0.042	0.078
2030	0.015	0.044	0.063	0.116
2031	0.020	0.058	0.083	0.154
2032	0.025	0.071	0.102	0.190
2033	0.030	0.086	0.122	0.227
2034	0.034	0.095	0.135	0.252
2035	0.038	0.105	0.148	0.279
2036	0.041	0.113	0.159	0.300
2037	0.044	0.121	0.170	0.322
2038	0.047	0.129	0.181	0.344
2039	0.050	0.136	0.190	0.362

Emissions Year	Discount Rate and Statistic (million 2020$)			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2040	0.052	0.140	0.196	0.372
2041	0.054	0.143	0.200	0.383
2042	0.055	0.146	0.204	0.391
2043	0.056	0.148	0.206	0.395
2044	0.057	0.150	0.208	0.399
2045	0.058	0.151	0.209	0.403
2046	0.060	0.153	0.212	0.410
2047	0.061	0.155	0.214	0.414
2048	0.062	0.157	0.216	0.420
2049	0.063	0.160	0.219	0.426
2050	0.065	0.162	0.222	0.433
2051	0.067	0.165	0.226	0.438
2052	0.069	0.169	0.230	0.447
2053	0.070	0.172	0.234	0.456
2054	0.072	0.175	0.239	0.465
2055	0.074	0.179	0.243	0.473
2056	0.076	0.182	0.247	0.482
2057	0.078	0.186	0.252	0.492
2058	0.073	0.172	0.232	0.453
2059	0.067	0.156	0.211	0.412
2060	0.061	0.141	0.190	0.372
2061	0.055	0.127	0.170	0.336
2062	0.050	0.112	0.150	0.299
2063	0.044	0.098	0.130	0.262
2064	0.038	0.083	0.110	0.224
2065	0.032	0.069	0.091	0.187
2066	0.026	0.056	0.074	0.152
2067	0.021	0.044	0.058	0.120
2068	0.016	0.034	0.044	0.093
2069	0.013	0.026	0.034	0.072
2070	0.010	0.020	0.026	0.056
Cumulative PV	0.58	2.35	3.67	6.27
Annualized	0.05	0.14	0.20	0.37

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5, 3, 2.5 percent) is used to calculate the present value of SC-GHGs for internal consistency. Annual benefits shown are undiscounted values.

Table 14.4.10 Monetized Health Benefits from Changes in NO_X and SO_2 Emissions at Proposed Standard Level (TSL 5)

Emissions Year	Discount Rate and Pollutant (million 2020$)			
	NO_X ($PM_{2.5}$ and Ozone)		SO_2	
	7%	3%	7%	3%
2028	9.3	10.4	2.6	2.9
2029	18.8	21.0	4.8	5.3
2030	28.9	32.2	6.7	7.5
2031	39.0	43.6	8.3	9.2
2032	49.8	55.6	9.9	11.0
2033	60.5	67.5	11.8	13.2
2034	69.0	76.9	12.7	14.2
2035	77.6	86.5	14.1	15.7
2036	85.1	94.9	15.1	16.8
2037	92.6	103.2	16.1	17.9
2038	99.9	111.4	16.8	18.7
2039	106.8	119.0	17.7	19.7
2040	111.6	124.4	17.9	19.9
2041	113.7	126.8	17.9	19.9
2042	115.2	128.4	17.8	19.8
2043	116.7	130.1	17.8	19.8
2044	117.5	131.0	17.8	19.8
2045	118.1	131.7	17.8	19.8
2046	119.6	133.3	18.0	20.0
2047	120.8	134.6	18.0	20.0
2048	122.3	136.4	18.1	20.1
2049	123.4	137.5	18.2	20.3
2050	124.1	138.3	18.6	20.7
2051	125.0	139.3	18.7	20.8
2052	125.9	140.3	18.7	20.8
2053	126.7	141.3	18.8	20.9
2054	127.6	142.2	18.8	20.9
2055	128.4	143.1	18.9	21.0
2056	129.5	144.3	19.0	21.1
2057	130.7	145.7	19.0	21.1
2058	118.8	132.5	17.2	19.2
2059	106.9	119.2	15.5	17.2
2060	95.2	106.1	13.8	15.3
2061	83.5	93.1	12.1	13.4
2062	72.1	80.4	10.5	11.7
2063	61.0	68.0	9.0	10.0
2064	50.2	56.0	7.5	8.3

Emissions Year	Discount Rate and Pollutant (million 2020$)			
	NO_X ($PM_{2.5}$ and Ozone)		SO_2	
	7%	**3%**	**7%**	**3%**
2065	40.1	44.7	6.2	6.8
2066	30.9	34.4	4.9	5.5
2067	22.8	25.5	3.9	4.3
2068	16.3	18.2	3.0	3.3
2069	11.5	12.8	2.3	2.6
2070	8.2	9.1	1.8	2.0
2071	6.1	6.8	1.4	1.6
2072	4.8	5.4	1.2	1.3
2073	3.9	4.4	1.0	1.1
2074	3.2	3.6	0.8	0.9
2075	2.7	3.0	0.7	0.8
2076	2.2	2.5	0.6	0.6
2077	1.8	2.0	0.5	0.5
2078	1.5	1.7	0.4	0.4
2079	1.2	1.4	0.3	0.3
2080	1.0	1.1	0.3	0.3
2081	0.8	0.9	0.2	0.2
2082	0.7	0.7	0.2	0.2
2083	0.5	0.6	0.1	0.1
2084	0.4	0.5	0.1	0.1
2085	0.3	0.4	0.1	0.1
2086	0.3	0.3	0.1	0.1
2087	0.2	0.2	0.1	0.1
2088	0.2	0.2	0.0	0.0
2089	0.1	0.1	0.0	0.0
2090	0.1	0.1	0.0	0.0
2091	0.1	0.1	0.0	0.0
2092	0.1	0.1	0.0	0.0
2093	0.1	0.1	0.0	0.0
2094	0.0	0.0	0.0	0.0
2095	0.0	0.0	0.0	0.0
Cumulative PV	741	1939	124	312
Annualized	84	115	14	18

* Annual benefits shown are undiscounted values.

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

15.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes several aggregate impacts on electric utilities that DOE projects would result for each trial standard level (TSL).

15.2 ELECTRIC UTILITIES

The electric utility impact analysis is based on output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *Annual Energy Outlook (AEO).* The EIA publishes a Reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. The current analysis is based on results published for the *AEO 2022*.[2]

DOE's *AEO*-based methodology has a number of advantages:

- The assumptions used in the *AEO* reference case and side cases are fully documented and receive detailed public scrutiny.
- NEMS is updated each year, with each edition of the *AEO*, to reflect changes in energy prices, supply trends, regulations, *etc.*
- The comprehensiveness of NEMS permits the modeling of interactions among the various energy supply and demand sectors.
- Using EIA published reference and side cases to estimate the utility impacts enhances the transparency of DOE's analysis.

The details of the methodology vary based on the number and type of side cases published with each edition of the *AEO*. The approach adopted for this analysis is described in appendix 15A. A more detailed discussion of the general approach is presented in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3,4]

This chapter presents the results for pool heaters.

15.3 METHODOLOGY

DOE estimates the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of

[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview*.[1]

energy conservation standards. DOE represents these marginal impacts using time series of *impact factors.*

The impact factors are calculated based on output from NEMS for the *AEO 2022*. NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the *AEO* reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity types and technologies may change. Technology changes lead to a change in the proportion of fuel consumption to electricity generated (referred to as the heat rate). Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use. Changes in generation by fuel type lead in turn to changes in total power sector emissions of SO_2, NO_x, Hg, and CO_2.

DOE defined impact factors describing the change in emissions, installed capacity, and fuel consumption per unit reduction of site electricity demand. The impact factors vary by sector and end-use, as well as by year. DOE multiplied the impact factors by the stream of site energy savings calculated in the NIA (chapter 10) to produce estimates of the utility impacts. The utility impact factors are presented in appendix 15A. For pool heaters DOE used the impact factors for water heating in homes and commercial buildings.

15.4 UTILITY IMPACT RESULTS

15.4.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. The changes have been calculated based on the impact factors for capacity presented in appendix 15A. Units are megawatts of capacity per gigawatt-hour of site electricity use (MW/GWh).[b] Note that a negative number means an increase in capacity under a TSL.

[b] These units are identical to GW/TWh.

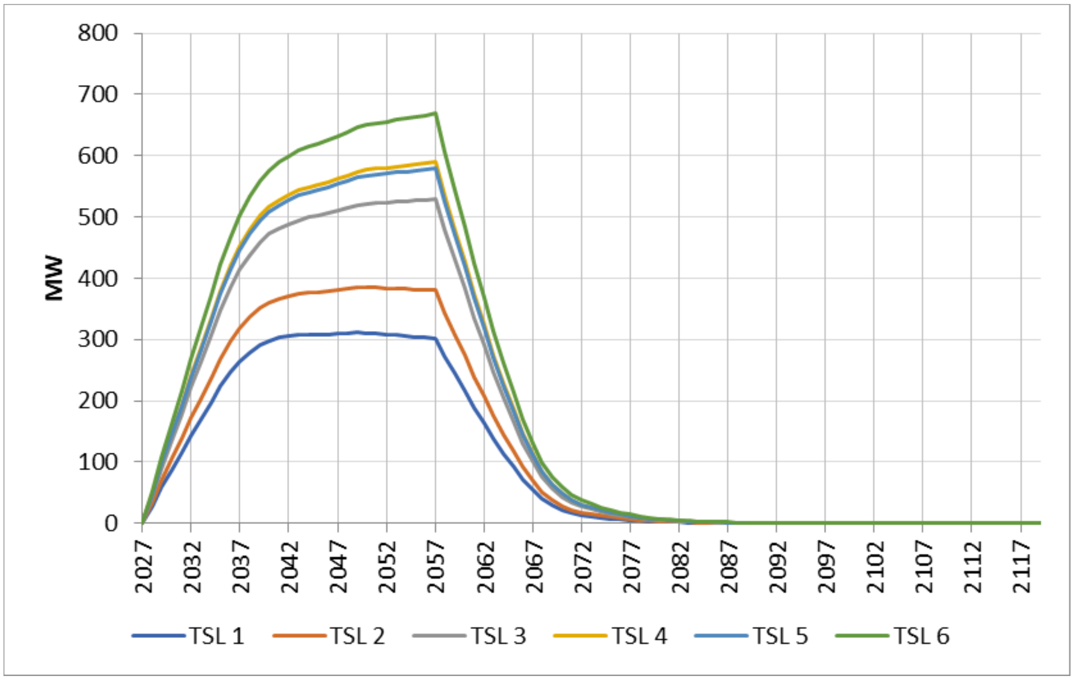

Figure 15.4.1 Pool Heaters: Total Electric Capacity Reduction

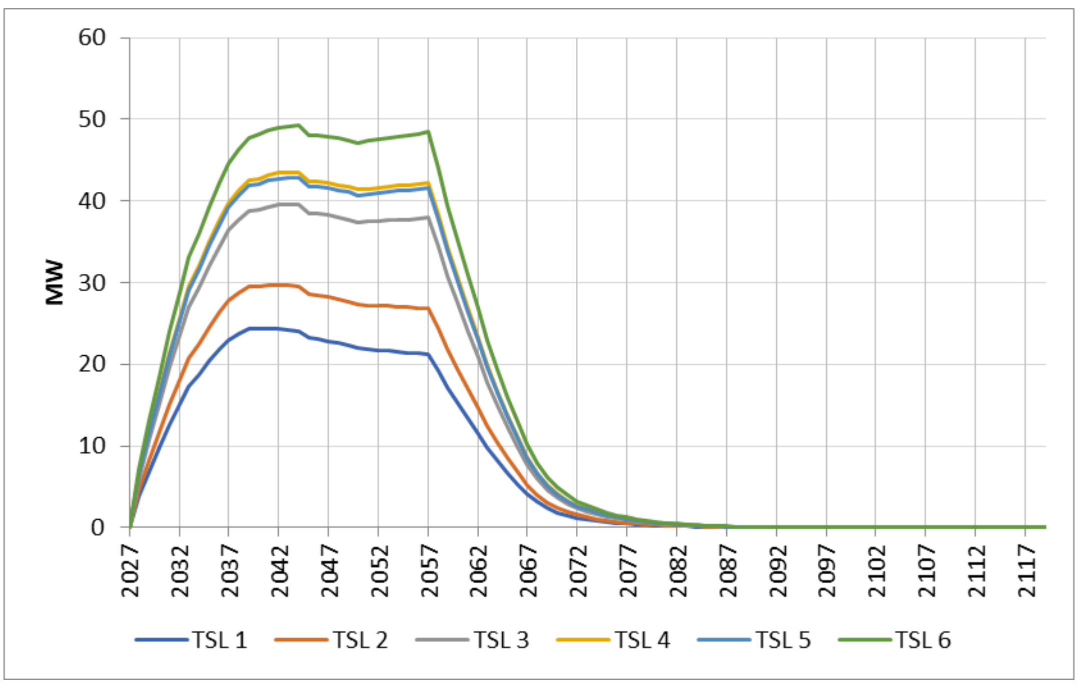

Figure 15.4.2 Pool Heaters: Coal Capacity Reduction

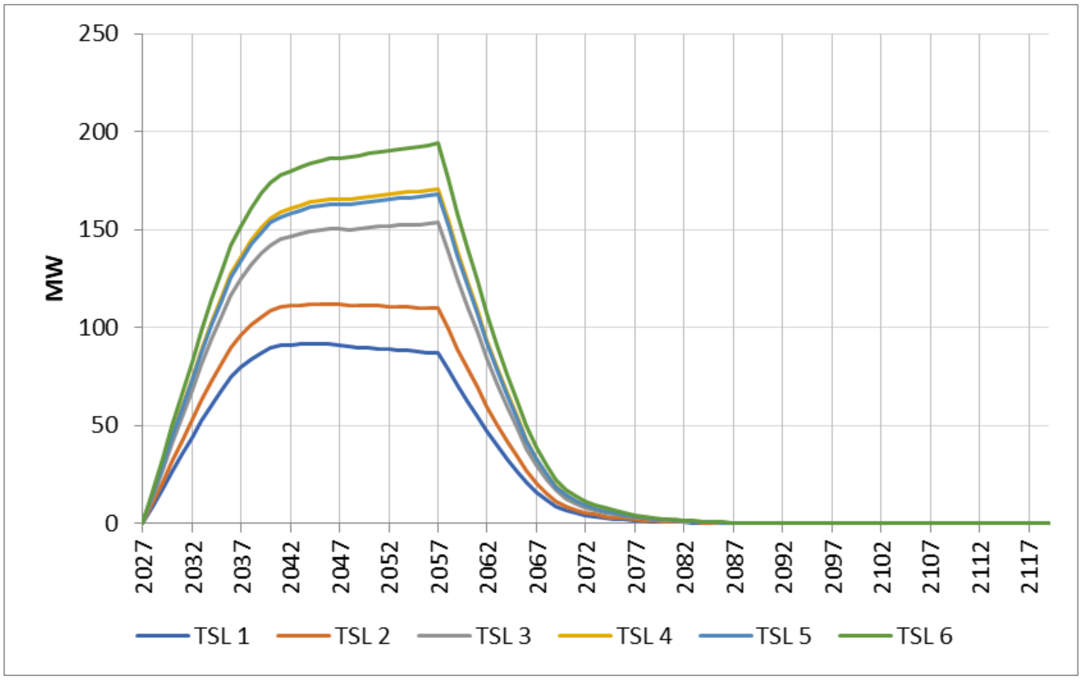

Figure 15.4.3 Pool Heaters: Gas Combined Cycle Capacity Reduction

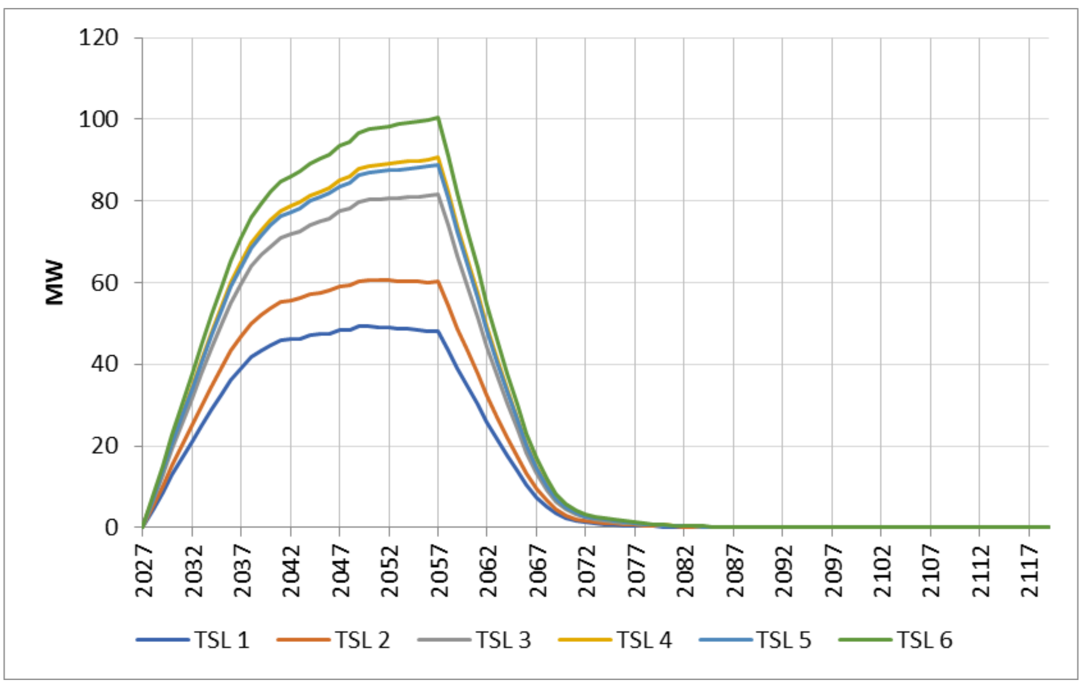

Figure 15.4.4 Pool Heaters: Peaking Capacity Reduction

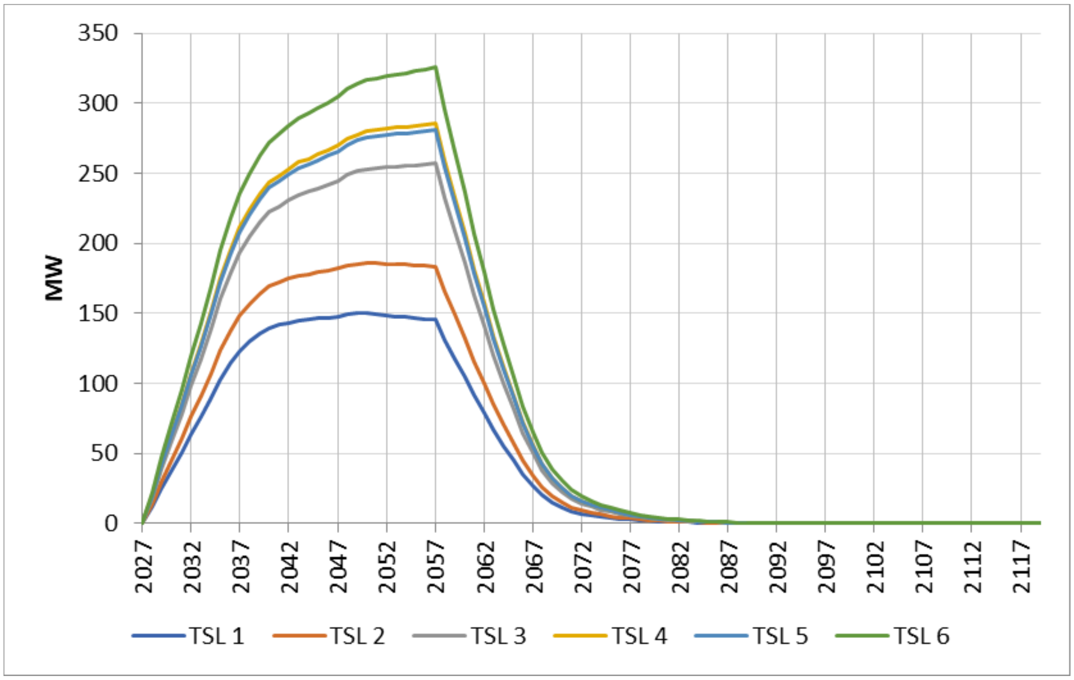

Figure 15.4.5 Pool Heaters: Renewables Capacity Reduction

15.4.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by fuel type. The change by fuel type has been calculated based on factors calculated as described in appendix 15A.

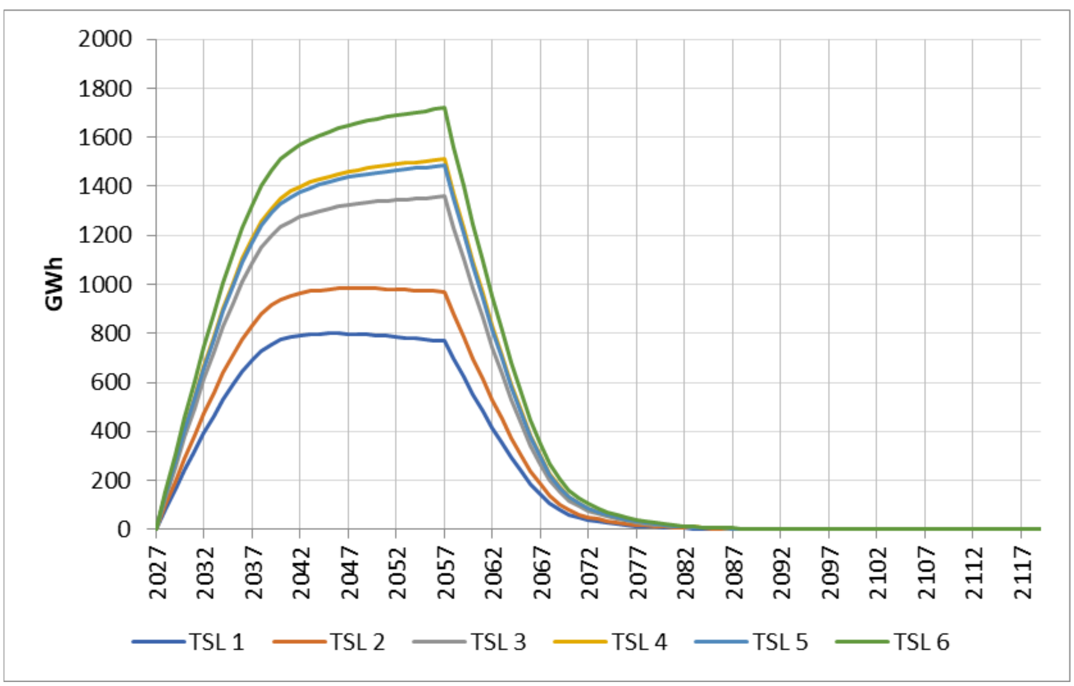

Figure 15.4.6 Pool Heaters: Total Generation Reduction

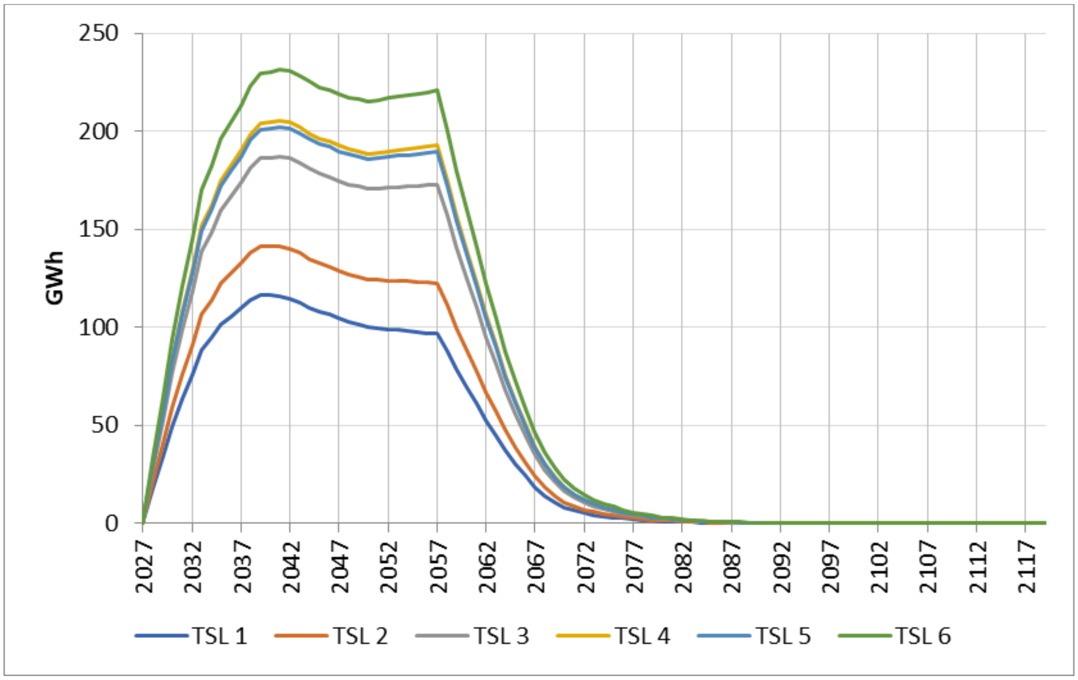

Figure 15.4.7 Pool Heaters: Coal Generation Reduction

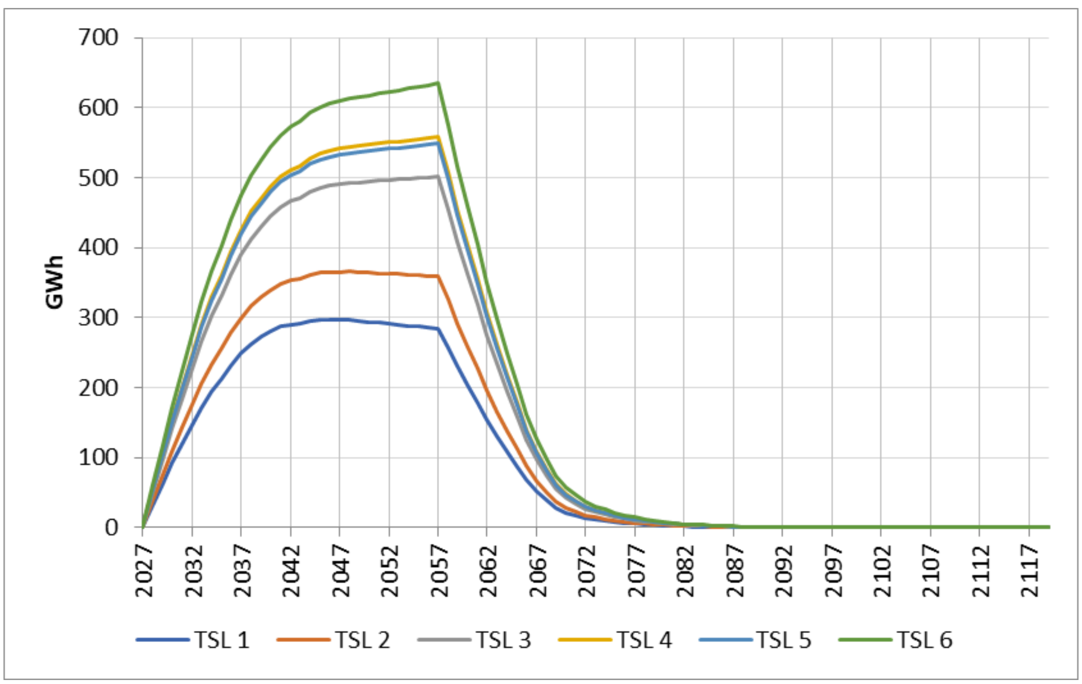

Figure 15.4.8 Pool Heaters: Gas Combined Cycle Generation Reduction

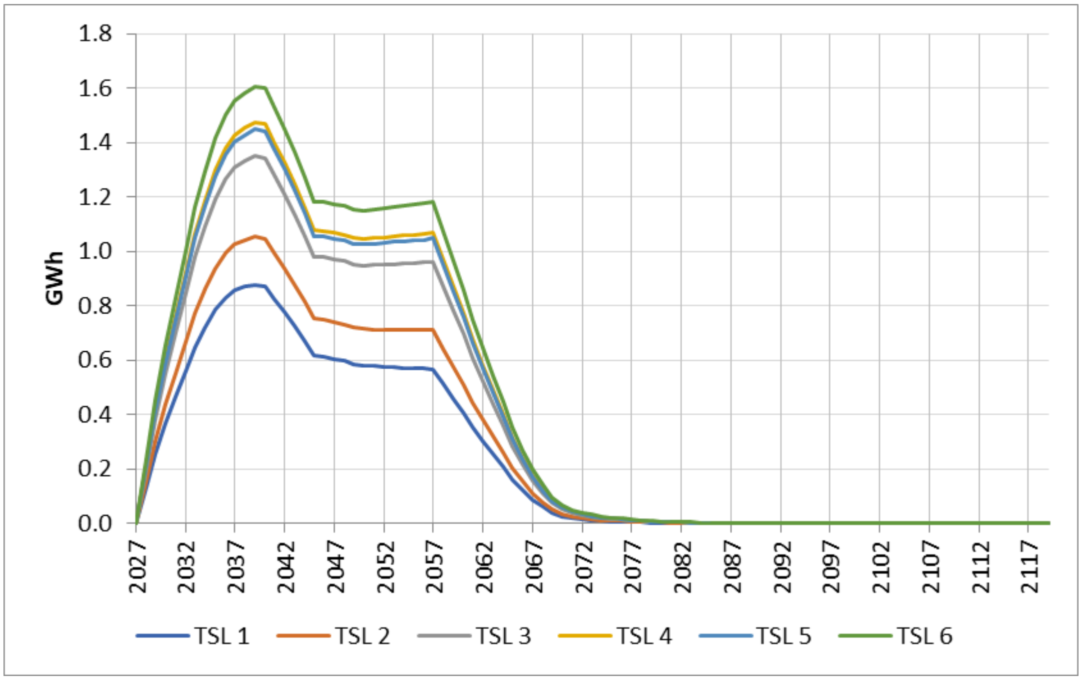

Figure 15.4.9 Pool Heaters: Oil Generation Reduction

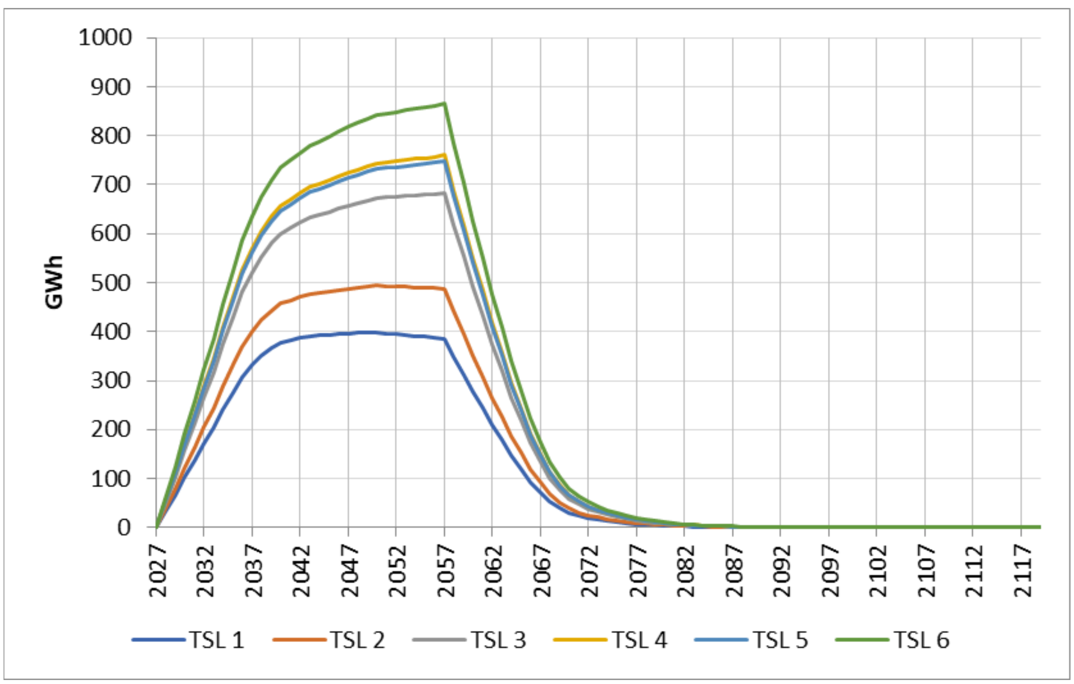

Figure 15.4.10 Pool Heaters: Renewables Generation Reduction

15.4.3 Results Summary

Table 15.4.1 presents a summary of the utility impact results for pool heaters.

Table 15.4.1 Pool Heaters: Summary of Utility Impact Results

	TSL					
	1	**2**	**3**	**4**	**5**	**6**
Installed Capacity Reduction (MW)						
2030	87	104	134	146	144	162
2040	224	269	348	380	374	422
2050	298	361	472	517	509	576
Electricity Generation Reduction (GWh)						
2030	243	291	376	409	403	457
2040	591	711	923	1,007	993	1,124
2050	775	939	1,232	1,350	1,330	1,511

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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16.1 INTRODUCTION

DOE's employment impact analysis for pool heaters is designed to estimate indirect national job creation or elimination resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating pool heaters. Job increases or decreases reported in this chapter are separate from the direct manufacturing sector employment impacts reported in the manufacturer impact analysis (Chapter 12), and reflect the employment impact of efficiency standards on all other sectors of the economy.

16.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent on new investment or not at all (i.e., they may remain "saved"). The standards may increase the purchase price of products, including the retail price plus sales tax, and increase installation costs.

Using the ImSET input/output econometric model of the U.S. economy, this analysis estimated the short-term effect of these expenditure impacts on net economic output and employment. DOE intends this analysis to quantify the indirect employment impacts of these expenditure changes. It evaluated direct employment impacts at manufacturers' facilities in the manufacturer impact analysis (see Chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] Because ImSET does not incorporate price changes, the employment effects predicted by ImSET would over-estimate the magnitude of actual job impacts over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore includes a qualitative discussion of how labor markets are likely to respond in the longer term. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

16.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 4 (Impact of Sector Energy Technologies)[2] as a successor to ImBuild,[3] a special-purpose version of the IMPLAN[4] national input/output model. ImSET estimates the employment and income effects of building energy technologies. In comparison with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy-efficiency investments in buildings.

In an input/output model, the level of employment in an economy is determined by the relationships between different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity, thus changes in the level of spending (*e.g.,* due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall national level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET collects estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (*e.g.,* changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in national output for each input-output sector. The model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general investment funds are diverted to sectors that manufacture, install, and maintain energy-efficient products. The increased cost of products leads to higher employment in the product manufacturing sectors and lower employment in other economic sectors. Second, commercial firm and residential spending are redirected from utilities toward firms that supply production inputs. Third, utility sector investment funds are released for use in other sectors of the economy. When consumers use less energy, utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the pool heater manufacturing sector estimated in Chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

16.4 SHORT-TERM RESULTS

The results in this section refer to impacts of pool heater standards relative to the base case. DOE disaggregated the impact of standards on employment into three component effects: increased capital investment costs, decreased energy costs, and changes in operations and maintenance costs. DOE presents the summary impact.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the pool heater manufacturing sector, the energy generation sector, and the general consumer goods sector (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally increases the purchase price of pool heaters; this increase in expenditures causes an increase in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on energy, freeing up this money to be spent in other sectors. The reduction in energy demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on pool heaters and reduced expenditures on energy, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in that sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (*e.g.,* as more workers are hired they consume more goods, which generates more employment; the converse is true for workers laid off).

Table 16.4.1 present the modeled net employment impact from the rule in 2028, rounded to the nearest hundred jobs. Pool heaters are used in both residential and commercial sectors, with a projected split of 89% and 11% in 2028, respectively. The majority of pool heaters (93%) are domestically produced, with the remaining 7% imported. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported products. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported pool heaters returns to the U.S. economy and all of the money spent on imported pool heaters returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50% and 75% of the money spent on imported products is likely to return, with employment impacts falling within the ranges presented below.

Table 16.4.1 Net National Short-term Change in Employment (1000s of Jobs)

Trial Standard Level	2028	2033
TSL 1	0.0	0.2
TSL 2	0.0	0.3
TSL 3	0.0 to 0.1	0.4
TSL 4	0.0 to 0.1	0.4
TSL 5	0.0 to 0.1	0.4 to 0.5
TSL 6	-0.2 to 0.0	0.8 to 1.0

For context, the Congressional Budget Office projects that during the period analyzed, the unemployment rate will be approximately 4.1%, close to "full employment."[5] When an economy is at full employment any effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment.

16.5 LONG-TERM RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for electricity to decline over time and demand for other goods to increase. Since the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand. In equilibrium, this should lead to upward pressure on wages and a shift in employment away from electricity generation towards consumer goods. Note that in long-run equilibrium there is no net effect on total employment since wages adjust to bring the labor market into equilibrium. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will in general be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1. The ImSET model projections, assuming no price or wage effects until 2033, are included in the second column of Table 16.4.1.

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

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17.1 INTRODUCTION

The Administrator of the Office of Information and Regulatory Affairs ("OIRA") in the OMB has determined that the regulatory action in this document is a significant regulatory action under section (3)(f) of Executive Order (E.O.) 12866. Regulatory Planning and Review. 58 FR 51735 (October 4, 1993). For such actions, E.O. 12866 requires Federal agencies to provide "an assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable non-regulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives." 58 FR 51735, 51741.

To conduct this analysis, DOE used an integrated National Impact Analysis (NIA)-RIA model built on a modified[a] version of the NIA model discussed in chapter 10. DOE identified four non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency levels as the ones in the selected trial standard levels (TSL) for the pool heaters that are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1, which also includes the "no new regulatory action" alternative.[b] DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the selected standards for pool heaters.[c]

Table 17.1.1 Non-Regulatory Alternatives to National Standards

No New Regulatory Action
Consumer Rebates
Consumer Tax Credits
Manufacturer Tax Credits
Voluntary Energy Efficiency Targets

Sections 17.2 and 17.3 discuss the analysis of four selected policies listed in Table 17.1.1 (excluding the alternative of "No New Regulatory Action"). Section 17.4 presents the results of the policy alternatives.

[a] For this RIA, DOE developed an alternative NIA model where shipments in the policy case do not account for any price-elasticity effect, and energy savings are not affected by the rebound effect. DOE believes that the national benefits from standards calculated this way are more comparable to the benefits from the alternative policies. In addition, DOE populated the alternative NIA it developed with shipment weighted-average values of electric and gas pool heaters used in the residential and commercial sectors.

[b] In other RIAs DOE has evaluated the benefits from government bulk purchases. However, according to the 2009 Residential Energy Consumption Survey (http://www.eia.gov/consumption/residential/data/2009/), no housing units in public housing authority use pool heaters. Therefore, DOE assumed that there is no market for this alternative policy and, consequently, did not include it in this analysis.

[c] DOE did not evaluate the effects of alternative policies at TSL 1 or for gas pool heaters at TSLs 2, 3, and 4 because the market shares of equipment meeting the target efficiency levels set for each of these TSLs are zero.

17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the non-regulatory policy alternatives for pool heaters. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of this technical support document (TSD) describes the NIA spreadsheet model. Appendix 17A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meets the efficiency levels corresponding to each TSL. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet model. The primary model inputs revised were market shares of equipment meeting the target efficiency levels set for each TSL. The shipments of equipment for any given year reflect a distribution of efficiency levels. DOE assumed, for each TSL, that new energy efficiency standards would affect 100 percent of the shipments of products that did not meet the TSL target levels in the no-new-standards case, whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of pool heaters attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. However, operating costs generally decrease because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the selected standards. In some policy scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because government expenditures on tax credits and rebates would be covered to a significant extent by income taxes paid by consumers in the aggregate, DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the impact of each alternative.

- National Energy Savings (NES), given in quadrillion Btus (quads), describes the cumulative national energy saved over the lifetime of equipment purchased during the 30-year analysis period starting in the effective date of the policy (2028-2057).
- Net Present Value (NPV), represents the value of net monetary savings in 2022, expressed in 2021$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2028-2057). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating expenditures in the no-new-standards case and the present values of those costs in each

policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain because they depend on program implementation, marketing efforts, and on consumers' response to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will be met with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy and consulted with recognized experts to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each alternative policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new pool heaters relative to their no-new-standards case efficiency scenario (which involves no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same technology as required by standards (the target level), according to the minimum energy efficiency set for each TSL. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet the target level.

Table 17.2.1 shows the minimum energy efficiencies of the pool heaters product classes at each TSL.

Table 17.2.1 Energy Efficiency by TSL (TEi)

	Electric Pool Heater[d]	**Gas Pool Heaters**
TSL 1	387%	81.3%
TSL 2	483%	81.3%
TSL 3	534%	81.3%
TSL 4	551%	81.3%
TSL 5	**551%**	**83.3%**
TSL 6	595%	94.8%

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2028—through the end of the analysis period, which is 2057.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination,

[d] Electric pool heaters at all TSLs represent heat pump pool heaters.

such as voluntary efficiency targets implemented with consumer rebates or tax credits. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are therefore not additive, and the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that show the market penetration estimated under each non-regulatory policy for pool heaters.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the four non-regulatory policy alternatives to the standards selected for pool heaters. (Because the alternative of "No New Regulatory Action" has no energy or economic impacts, essentially representing the NIA no-new-standards case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of more efficient products both with and without each of the non-regulatory policy alternatives.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of pool heaters constitutes the no-new-standards case, as described in chapter 10, National Impact Analysis. The no-new-standards case provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero NES and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy-efficient equipment. This policy provides a consumer rebate for purchasing pool heaters that operate at the same efficiency levels as stipulated in each TSL.

17.3.2.1 Methodology

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. The study, performed by XENERGY, Inc.,[e] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized graphs, or penetration curves, that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE consulted with experts and reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies. The other methods, developed after the referenced XENERGY report was published,[2, 3, 4, 5, 6, 7, 8] used different approaches: other economic parameters (*e.g.,* payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models in use by energy efficiency program evaluation experts were so client-specific that generic relationships between economic parameters and consumer response could not be established.[5, 6] DOE decided that the most appropriate available method for this

[e] XENERGY is now owned by KEMA, Inc. (www.kema.com)

RIA was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new equipment primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (or implementation) curves for a policy measure. XENERGY calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (i.e., increased market share) of efficient equipment driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived market barriers (from no-barriers to extremely-high-barriers) to consumer purchase of high-efficiency equipment. DOE adjusted the XENERGY former penetration curves based on expert advice founded on more recent utility program experience.[5, 6, 9]

DOE modeled the effects of a consumer rebate policy for pool heaters by determining, for each TSL, the increase in market penetration of equipment meeting the target level relative to their market penetration in the no-new-standards case. It used the interpolation method presented in Blum et al (2011)[10] to create customized penetration curves based on relationships between actual no-new-standards case market penetrations and actual B/C ratios. To inform its estimate of B/C ratios provided by a rebate program DOE performed a thorough nationwide search for existing rebate programs for pool heaters. It gathered data on utility or agency rebates throughout the nation for this equipment, and used this data to calibrate the customized penetration curves it developed for each product class covered by this RIA so they can best reflect the market barrier levels that consumer rebates for pool heaters would face. Section 17.3.2.2 shows the resulting interpolated curves used in the analysis.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of pool heaters via a rebate that would pay part of the increased installed cost of efficient pool heaters that meet the target efficiency levels compared to units meeting the baseline efficiency level.[f] To inform its estimate of an appropriate rebate amount, DOE performed a thorough nationwide search for existing rebate programs for pool heaters in June, 2021. It found a total of 4 rebates relevant to this analysis (2 electric pool heater rebates and 2 gas pool heater rebates). DOE assumed that the average rebate values identified for electric pool heaters and gas heaters, respectively, represent market rebate values for the two product classes covered by this RIA. Therefore, DOE applied these values in the calculation of the B/C ratio of electric and gas pool heaters under the effect of

[f] The baseline technology is defined in the engineering analysis, chapter 5, as the technology that represents the basic characteristics of pool heaters. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.

consumer rebates. (Appendix 17A identifies the rebate program.) DOE assumed that rebates would remain in effect at the same level throughout the forecast period (2028-2057).

DOE first calculated the B/C ratio of a pool heater without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[g] (B) between a unit meeting the target level and a baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the rebate had a larger B/C ratio. Table 17.3.1 shows the effect of consumer rebates for each TSL on the B/C ratio of pool heaters shipped in the first year of the analysis period.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates

	TSL 1	TSL 2	TSL 3	TSL 4	**TSL 5**	TSL 6
Electric Pool Heater						
B/C Ratio without Rebate	-	24.1	20.8	17.0	**17.0**	13.7
Rebate Amount (2021$)	-	700.00	700.00	700.00	**700.00**	700.00
B/C Ratio with Rebate	-	Infinite**	Infinite**	185.3	**185.3**	49.9
Estimated Market Barriers	-	Low-Mod*	High	High	**High**	High
Gas Pool Heater						
B/C Ratio without Rebate	-	-	-	-	**3.6**	2.2
Rebate Amount (2021$)	-	-	-	-	**575.00**	575.00
B/C Ratio with Rebate	-	-	-	-	**Infinite****	4.3
Estimated Market Barriers	-	-	-	-	**Low-Mod***	Low-Mod*

*Low-Mod: Low-to-Moderate market barriers.
**When a rebate covers in full the incremental installed cost, the denominator of the benefit/cost ratio is zero, and the ratio is therefore represented as 'infinite.' This means that the market penetration of efficient pool heaters will be the highest possible share estimated for this equipment, given the market barriers estimated for the product class.

DOE used the B/C ratio along with the customized penetration curve shown in Figure 17.3.1 to estimate the percentage of consumers who would purchase pool heaters that meet the target levels both with and without a rebate incentive. The estimated levels of market barriers corresponding to the penetration curve DOE calculated to represent the market behavior for pool heaters at the selected TSL are indicated (bolded) in Table 17.3.1.

[g] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

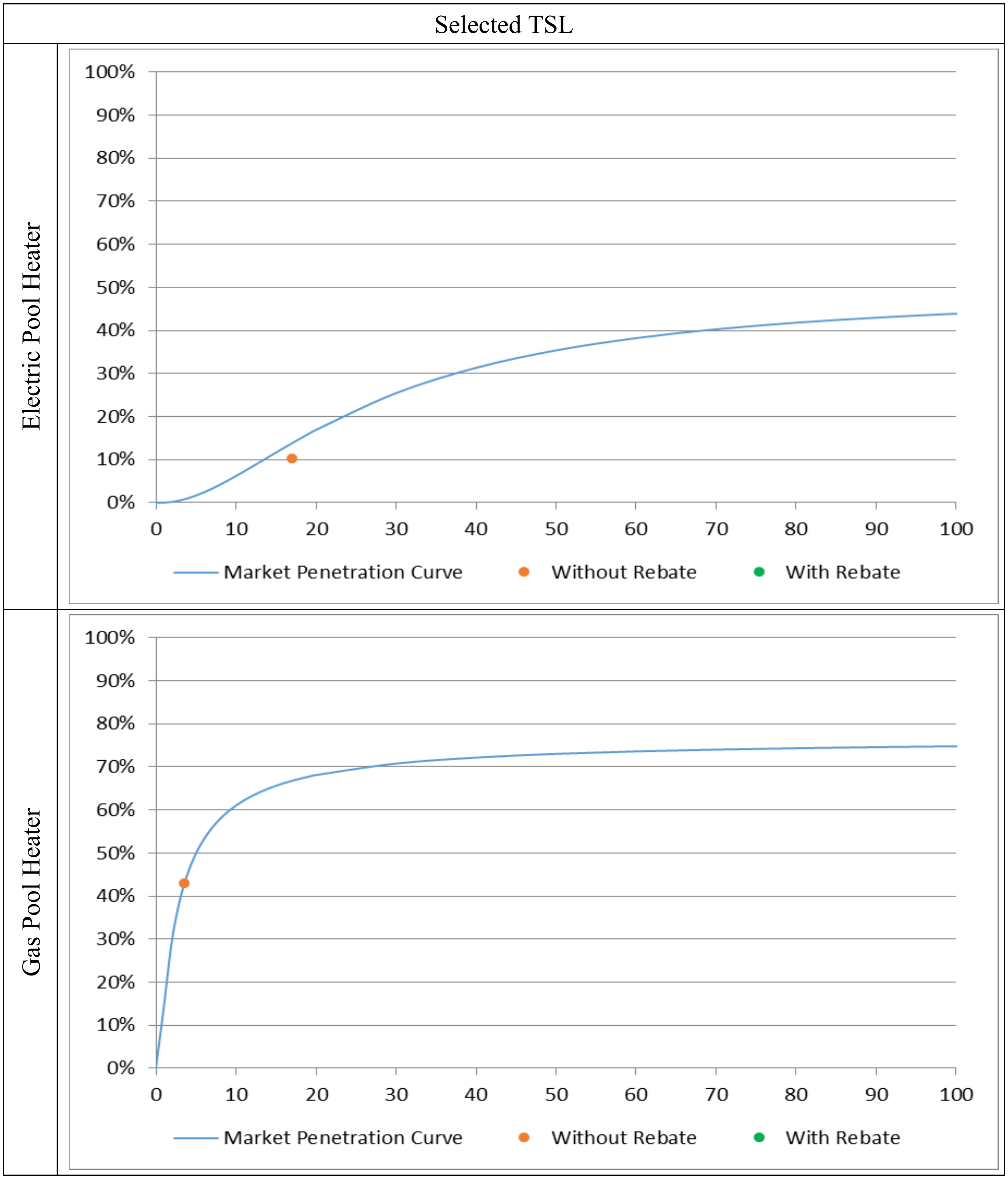

Figure 17.3.1 Market Penetration Curves for Pool Heaters[h]

[h] Because the B/C ratio with rebates exceeds 100 for electric pool heaters and is infinite for gas pool heaters, the data points that refer to the market penetration with rebates are not shown in the charts.

DOE next estimated the percent increase represented by the change in penetration rate shown on the corresponding penetration curve. It then added this percent increase to the market share of units that meet the target level in the no-new-standards case to obtain the market share of units that meet the target level in the rebate policy case.

Table 17.3.2 summarizes DOE's assumptions for pool heaters regarding the market penetration of products in 2028 that meet the target levels at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2028 Attributable to Consumer Rebates

	TSL 1	TSL 2	TSL 3	TSL 4	**TSL 5**	TSL 6
Electric Pool Heater						
Base-Case Market Share	-	64.8%	10.2%	10.2%	**10.2%**	3.3%
Policy Case Market Share	-	73.3%	50.0%	47.4%	**47.4%**	35.4%
Increased Market Share	-	8.5%	39.8%	37.2%	**37.2%**	32.1%
Gas Pool Heater						
Base-Case Market Share	-	-	-	-	**42.9%**	9.0%
Policy Case Market Share	-	-	-	-	**76.6%**	23.0%
Increased Market Share	-	-	-	-	**33.7%**	14.0%

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for pool heaters.

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy-efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[11, 12] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credit would be the same as the corresponding rebate amount discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[13]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of pool heaters, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchase energy-efficient products.[14] Those tax credits were in effect in 2006 and 2007, expired in 2008, were reinstated for 2009–2010 by the American Recovery and Reinvestment Act of 2009 (ARRA), extended by Congress for 2011 with some modifications, and expired at the end of 2011.[15, 16] The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[17] DOE reviewed Internal Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to pool heaters to warrant adjusting its analysis method for the Consumer Tax Credits policy case. Appendix 17A contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis of Oregon's tax credits for clothes washers to provide support for its assumptions.[18] In that previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent efficiency. This finding supports its original assumption that participation in a tax credit program would be about 60 percent of participation in a rebate program. Additional discussion of State tax credits for Oregon and other states is in appendix 17A.

DOE applied the assumed 60 percent participation described above to the increase in penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for pool heaters (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for pool heaters regarding the market penetration of products in 2028 that meet the target levels at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2028 Attributable to Consumer Tax Credits

	TSL 1	TSL 2	TSL 3	TSL 4	**TSL 5**	TSL 6
Electric Pool Heater						
Base-Case Market Share	-	64.8%	10.2%	10.2%	**10.2%**	3.3%
Policy Case Market Share	-	69.9%	34.1%	32.5%	**32.5%**	22.5%
Increased Market Share	-	5.1%	23.9%	22.3%	**22.3%**	19.3%
Gas Pool Heater						
Base-Case Market Share	-	-	-	-	**42.9%**	9.0%
Policy Case Market Share	-	-	-	-	**63.1%**	17.4%
Increased Market Share	-	-	-	-	**20.2%**	8.4%

The increased market shares attributable to consumer tax credits shown in Table 17.3.3 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for pool heaters that meet the efficiency level for the selected TSL.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce pool heaters that meet the target efficiency levels at each TSL, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[i] Because the direct price effect is approximately equivalent to the announcement effect,[11] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. Thus, the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[19] Those manufacturer tax credits have been in effect for dishwashers, clothes washers and refrigerators produced beginning in 2009. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the increase in penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In

[i] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curves it developed for pool heaters. (See Figure 17.3.1).

Table 17.3.4 summarizes DOE's assumptions for pool heaters regarding the market penetration of products in 2028 that meet the target levels at each TSL given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2028 Attributable to Manufacturer Tax Credits

	TSL 1	TSL 2	TSL 3	TSL 4	**TSL 5**	TSL 6
Electric Pool Heater						
Base-Case Market Share	-	64.8%	10.2%	10.2%	**10.2%**	3.3%
Policy Case Market Share	-	67.4%	22.2%	21.4%	**21.4%**	12.9%
Increased Market Share	-	2.5%	11.9%	11.1%	**11.1%**	9.6%
Gas Pool Heater						
Base-Case Market Share	-	-	-	-	**42.9%**	9.0%
Policy Case Market Share	-	-	-	-	**53.0%**	13.2%
Increased Market Share	-	-	-	-	**10.1%**	4.2%

The increased market shares attributable to a manufacturer tax credit shown in Table 17.3.4 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for pool heaters.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of pool heaters to gradually stop producing units that operate below the efficiency levels set for each TSL. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program with impacts similar to those of the ENERGY STAR labeling program conducted by the Environmental Protection Agency (EPA) and DOE in conjunction with industry partners. The ENERGY STAR program specifies the minimum energy efficiencies that various products must have to receive the ENERGY STAR label. ENERGY STAR encourages consumers to purchase efficient products via marketing that promotes consumer label recognition, various incentive programs that adopt the ENERGY STAR specifications, and manufacturers' promotion of their qualifying appliances. ENERGY STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the ENERGY STAR program.

Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products. Program efforts generally involve a combination of information dissemination and utility or agency rebates. The analyses have been based on State-specific data on percentages of shipments of various appliances that meet ENERGY STAR specifications. The analyses generally have concluded that the market penetration of ENERGY STAR-qualifying appliances is higher in regions or States where ancillary promotional programs have been active.[20, 21, 22]

DOE believes that informational incentive programs – like ENERGY STAR, or any other labeling program sponsored by industry or other organizations – are likely to reduce the market barriers to more efficient products over time. During the rebate analysis, when assessing the B/C ratio and market penetration in the no-new-standards case for pool heaters, DOE observed market barriers for pool heaters that are more efficient than baseline pool heaters. DOE estimates that voluntary energy efficiency targets could reduce these barriers over 10 years. Table 17.3.5 presents the levels of market barriers DOE estimated for pool heaters in the no-new-standards case and in the policy case of voluntary energy efficiency targets for the selected TSL (TSL 5). DOE followed the methodology presented by Blum et al (2011)[10] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient pool heaters.[j] The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

Table 17.3.5 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets (TSL 5)

	No-new-standards Case	**Voluntary Energy Efficiency Targets**
Electric Pool Heater	High	Moderate-High
Gas Pool Heater	Low-Moderate	Low

Table 17.3.6 summarizes DOE's assumptions for pool heaters regarding the market penetration of products in 2028 that meet the target levels at each TSL given voluntary energy efficiency targets. Table 17.3.7 expands on Table 17.3.6 to include, for the selected TSL, DOE's assumptions regarding the market penetration of units in selected years.

Table 17.3.6 Market Penetrations in 2028 Attributable to Voluntary Energy Efficiency Targets

	TSL 1	TSL 2	TSL 3	TSL 4	**TSL 5**	TSL 6
Electric Pool Heater						
Base-Case Market Share	-	64.8%	10.2%	10.2%	**10.2%**	3.3%
Policy Case Market Share	-	65.8%	20.6%	16.4%	**16.4%**	12.4%
Increased Market Share	-	1.0%	10.4%	6.2%	**6.2%**	9.1%
Gas Pool Heater						
Base-Case Market Share	-	-	-	-	**42.9%**	9.0%
Policy Case Market Share	-	-	-	-	**43.7%**	14.5%
Increased Market Share	-	-	-	-	**0.7%**	5.5%

[j] For the calculation of B/C ratios DOE discounted the cash flow of the operating cost savings to the purchase year using a 7 percent discount rate.

Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for TSL 5

	2028	2037	2057
Electric Pool Heater			
Base-Case Market Share	10.2%	10.2%	10.2%
Policy Case Market Share	16.4%	34.7%	34.3%
Increased Market Share	6.2%	24.5%	24.1%
Gas Pool Heater			
Base-Case Market Share	42.9%	42.9%	42.9%
Policy Case Market Share	43.7%	50.9%	51.5%
Increased Market Share	0.7%	8.0%	8.6%

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.6 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole forecast period. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for pool heaters that meet the efficiency level for the selected TSL. Because of the decrease in the market barriers level over the first 10 years of the analysis period, the market penetration of more efficient pool heaters significantly increases over that period.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 and Figure 17.4.2 show the effects of each non-regulatory policy alternative on the market penetration of more efficient pool heaters. Relative to the no-new-standards case, the alternative policy cases increase the market shares that meet the target level. Recall the selected standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the more efficient technology.

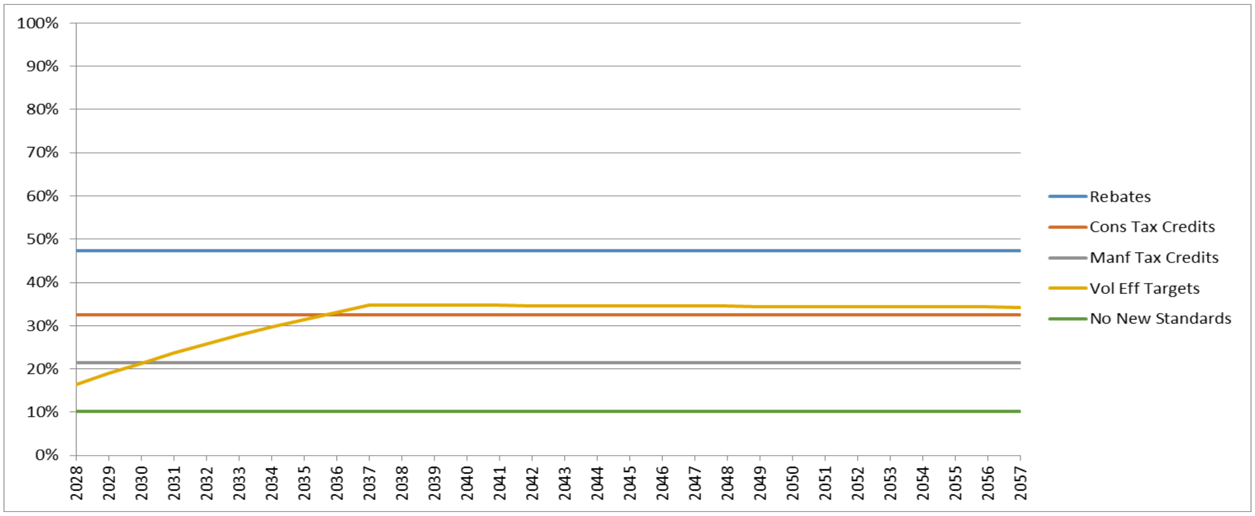

Figure 17.4.1 Market Penetration of Efficient Electric Pool Heater (TSL 5)

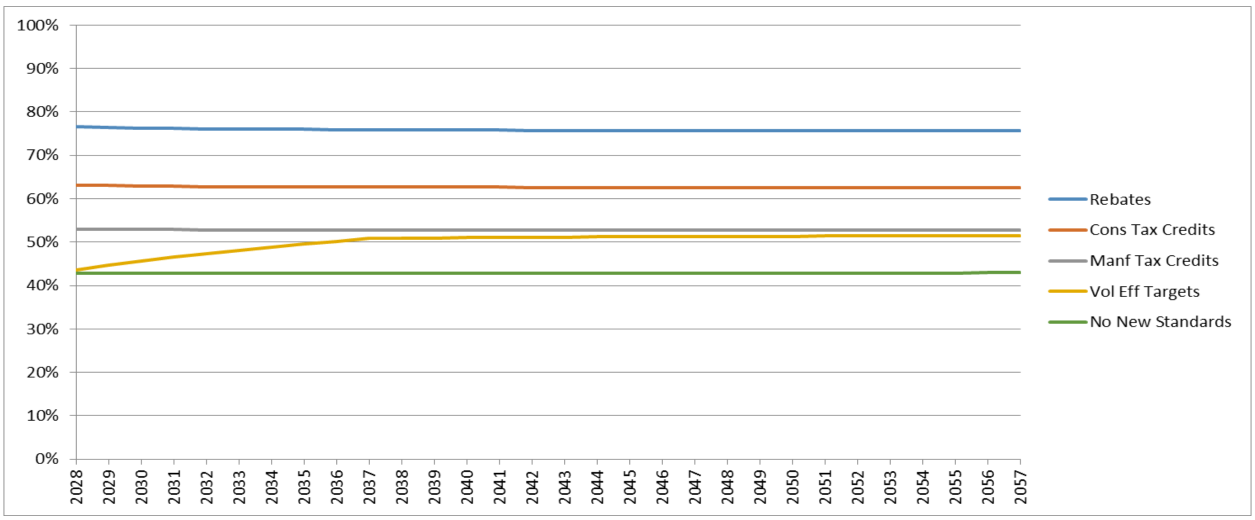

Figure 17.4.2 Market Penetration of Efficient Gas Pool Heater (TSL 5)

Table 17.4.1 shows the national energy savings and net present value for the four non-regulatory policy alternatives analyzed in detail for pool heaters. The target level for each policy corresponds to the same efficient technology selected for standards in TSL 5. The case in which no regulatory action is taken with regard to pool heaters constitutes the no-new-standards case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the tables include the impacts of the selected standards calculated as described in footnote ‘a’. Energy savings are given in quadrillion British thermal units (quads) of primary energy savings.[k] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent. Under both discount rates, the selected standards carry a higher NPV than any non-regulatory alternative.

[k] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in Table 17.4.1 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

The policy with the highest projected cumulative energy savings is consumer rebates. Savings from tax credits range from 16.7 percent to 33.5 percent of the savings from selected standards calculated as described in footnote 'a'. Voluntary energy efficiency targets have the lowest cumulative energy savings. Overall, the energy saving benefits from the alternative policies, range from 10.9 percent to 57.7 percent of the benefits from the selected standards calculated as described in footnote 'a'.

Table 17.4.1   Impacts of Non-Regulatory Policy Alternatives (TSL 5)

Policy Alternative	**Energy Savings*** *quads*		**Net Present Value*** *million 2021$*	
			7% Disc Rate	3% Disc Rate
Consumer Rebates	0.219	57.7%***	219	653
Consumer Tax Credits	0.127	33.5%	131	392
Manufacturer Tax Credits	0.064	16.7%	65.6	196
Voluntary Energy Efficiency Targets	0.042	10.9%	33.6	146
Selected Standards**	0.380	100.0%	405	1,220

* For products shipped 2028-2057.

** Calculated as described in footnote 'a'.

*** The percentages show how the energy savings from each policy alternative compare to the primary energy savings from the selected standards (represented in the table as 100%), when the latter are calculated as described in footnote 'a'.

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APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

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DETAILED DATA FOR PRODUCT PRICE MARKUPS

6A.1 DETAILED POOL CONTRACTOR AND MECHANICAL CONTRACTOR DATA

Chapter 6 provides revenues and costs in aggregated form by 'Cost of Goods Sold' and a list of cost categories under 'Gross Margin, for pool contractor in residential applications and mechanical contractor in commercial applications The tables are based on the 2017 Census of Business for "*Plumbing, Heating and Air-Conditioning Contractors"* (NAICS 238220).[1] The complete income statement for that sector is shown in Table 6A.1.1 by both dollar value and percentage terms.

Table 6A.1.1 Pool Contractor Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**145,663,613**	**70.64**	
Total payroll, construction workers wages	55,924,117	27.12	
Cost of materials, components, and supplies	66,809,886	32.40	
Cost of construction work subcontracted out to others	15,843,400	7.68	
Cost of purchased lands	26,092	0.01	
Total cost of selected power, fuels, and lubricants	4,480,245	2.17	
Purchased professional and technical services	1,323,472	0.64	
Rental costs of machinery and equipment	1,062,676	0.52	
Refuse removal (including hazardous waste) services	193,725	0.09	
Gross Margin	**60,544,603**	**29.36**	
Payroll Expenses	**24,436,263**	**11.85**	**Baseline**
Total payroll, other employees wages	17,749,793	8.61	
Total fringe benefits	5,623,693	2.73	
Temporary staff and leased employee expenses	1,062,777	0.52	
Occupancy Expenses	**2,988,327**	**1.45**	**Baseline**
Rental costs of buildings	1,413,799	0.69	
Communication services	932,999	0.45	
Cost of repair to machinery and equipment	641,529	0.31	
Other Operating Expenses	**15,064,680**	**7.31**	**Baseline & Incremental**
Data processing and other purchased computer services	222,424	0.11	
Expensed computer hardware and other equipment	444,416	0.22	
Expensed purchases of software	250,992	0.12	
Advertising and promotion services	1,061,264	0.51	
All other expenses	9,288,684	4.50	
Taxes and license fees	1,058,118	0.51	
Total depreciation ($1,000)	2,738,782	1.33	
Net Profit Before Income Taxes	**18,055,333**	**8.76**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Plumbing, Heating, and Air-Conditioning Contractors: 2017. Sector 23: 238220. Construction: Geographic Area Series. Detailed Statistics for Establishments: 2017.

6A.2 DETAILED POOL RETAILER COST DATA

Chapter 6 provides pool retailer revenue and costs based on data for miscellaneous store retailers from the 2017 U.S. Census Annual Retail Trade Survey ("ARTS").[2] Further disaggregated breakdowns of costs used to scale the incremental markup are shown in in Table 6A.2.1.

Table 6A.2.1 Pool Retailers Expenses and Markups

	Amount ($1,000,000)
Sales	$123,182
Cost of Goods Sold (CGS)	$59,962
Gross Margin (GM)	$63,220
Labor & Occupancy Expenses ("Invariant")	
Annual payroll	$18,639
employer costs for fringe benefit	$3,514
Contract labor costs including temporary help	$417
Purchased utilities, total	$1,287
Cost of purchased repair and maintenance services	$792
Cost of purchased professional and technical services	$1,150
Purchased communication services	$512
Lease and rental payments for land, buildings, structurers, store space and offices	$7,135
Subtotal:	$33,446
Other Operating Expenses & Profit ("Variant")	
Expensed equipment	$186
Cost of purchased packaging and containers	$297
Other materials and supplies not for resale	$953
Cost of purchased transportation, shipping and warehousing services	$1,065
Cost of purchased advertising and promotional services	$2,169
Cost of purchased software	$138
Cost of data processing and other purchased computer services, except communications	$191
Commission expenses	$471
Depreciation and amortization charges	$1,774
Taxes and license fees	$658
Other operating expenses	$5,481
Gross profit before tax	$16,391
Subtotal:	$29,774
Baseline Markup = Sales/CGS	2.05
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	1.50

Source: U.S. Census Bureau 2017 Annual Retail Trade Survey (NAICS 453 Miscellaneous store retailers.

6A.3 DETAILED POOL BUILDER COST DATA

Chapter 6 provides pool builder revenues and costs in aggregated form by 'Cost of Goods Sold' and a list of cost categories under 'Gross Margin.' The tables are based on the 2017 Census of Business for "*All Other Specialty Trade Contractors*" (NAICS 238990).[3] The complete income statement for that sector is shown in Table 6A.3.1 by both dollar value and percentage terms.

Table 6A.3.1 Pool Builder Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**35,249,999**	**67.53**	
Total payroll, construction workers wages	11,401,326	21.84	
Cost of materials, components, and supplies	16,818,176	32.22	
Cost of construction work subcontracted out to others	3,690,671	7.07	
Cost of purchased lands	11,534	0.02	
Total cost of selected power, fuels, and lubricants	2,034,296	3.90	
Purchased professional and technical services	918,450	1.76	
Rental costs of machinery and equipment	310,064	0.59	
Refuse removal (including hazardous waste) services	65,482	0.13	
Gross Margin	**16,948,186**	**32.47**	
Payroll Expenses	**5,285,213**	**10.13**	**Baseline**
Total payroll, other employees wages	4,061,911	7.78	
Total fringe benefits	984,219	1.89	
Temporary staff and leased employee expenses	239,083	0.46	
Occupancy Expenses	**1,185,303**	**2.27**	**Baseline**
Rental costs of buildings	355,098	0.68	
Communication services	190,296	0.36	
Cost of repair to machinery and equipment	639,909	1.23	
Other Operating Expenses	**4,991,109**	**9.56**	**Baseline & Incremental**
Data processing and other purchased computer services	42,644	0.08	
Expensed computer hardware and other equipment	84,824	0.16	
Expensed purchases of software	39,115	0.07	
Advertising and promotion services	189,427	0.36	
All other expenses	2,791,443	5.35	
Taxes and license fees	323,953	0.62	
Total depreciation ($1,000)	1,519,703	2.91	
Net Profit Before Income Taxes	**5,486,561**	**10.51**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. All Other Specialty Trade Contractor. Sector 23: 238990. Construction, Industry Series, General Summary: Detailed Statistics for Establishments: 2017.

6A.4 DETAILED WHOLESALER COST DATA

Chapter 6 shows wholesaler revenues and costs in aggregated form. Table 6A.4.1 shows the breakdown of operating expenses for the hardware and plumbing and heating equipment and supplies merchant wholesale sector using the 2017 Annual Wholesale Trade Survey.[1]

Table 6A.4.1 Disaggregated Costs and Expenses for Wholesalers

	Amount ($1,000,000)
Sales	140,474
Cost of Goods Sold (CGS)	100,101
Gross Margin (GM)	41,373
Labor & Occupancy Expenses ("Fixed")	
Annual payroll	15,441
Employer costs for fringe benefit	3,589
Contract labor costs including temporary help	405
Purchased utilities, total	404
Purchased Repairs and Maintenance to Machinery and Equipment	269
Purchased Repairs and Maintenance to Buildings, Structures, and Offices	197
Purchased communication services	348
Lease and Rental Payments for Machinery, Equipment, and Other Tangible Items	302
Lease and Rental Payments for Land, Buildings, Structures, Store Space, and Offices	1,683
Subtotal:	22,635
Other Operating Expenses & Profit ("Variable")	
Expensed equipment	122
Purchases of other materials, parts, and supplies (not for resale)	444
Cost of purchased packaging and containers	305
Cost of purchased transportation, shipping and warehousing services	1,777
Cost of purchased professional and technical services	568
Cost of purchased advertising and promotional services	973
Cost of purchased software	137
Cost of data processing and other purchased computer services	154
Depreciation and amortization charges	1,217
Commission expenses	527
Taxes and license fees (mostly income taxes)	394
Other operating expenses	2,586
Net profit before tax (Operating profit)	8,534
Subtotal:	17,738
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	**1.177**

Source: U.S. Census, 2017 Annual Wholesale Trade Survey.

6A.5 DETAILED GENERAL CONTRACTOR COST DATA

Chapter 6 shows commercial building general contractor revenues and costs in aggregated form. Table 6A.5.1 shows the complete breakdown of costs and expenses of commercial building contractor based on the Commercial Building Construction series (NAICS 236220) from the 2017 Economic Census.[4]

Table 6A.5.1 Commercial General Contractor Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**343,317,381**	**79.29**	
Total payroll, construction workers wages	29,438,318	6.80	
Cost of materials, components, and supplies	118,310,102	27.32	
Cost of construction work subcontracted out to others	184,272,890	42.56	
Cost of purchased lands	106,526	0.02	
Total cost of selected power, fuels, and lubricants	7,778,246	1.80	
Purchased professional and technical services	1,483,597	0.34	
Rental costs of machinery and equipment	1,697,510	0.39	
Refuse removal (including hazardous waste) services	230,192	0.05	
Gross Margin	**89,692,056**	**20.71**	
Payroll Expenses	**27,040,957**	**6.24**	**Baseline**
Total payroll, other employees wages	20,515,276	4.74	
Total fringe benefits	5,483,998	1.27	
Temporary staff and leased employee expenses	1,041,683	0.24	
Occupancy Expenses	**2,368,100**	**0.55**	**Baseline**
Rental costs of buildings	1,113,219	0.26	
Communication services	644,100	0.15	
Cost of repair to machinery and equipment	610,781	0.14	
Other Operating Expenses	**14,310,829**	**3.30**	**Baseline & Incremental**
Data processing and other purchased computer services	281,555	0.07	
Expensed computer hardware and other equipment	461,023	0.11	
Expensed purchases of software	323,275	0.07	
Advertising and promotion services	531,679	0.12	
All other expenses	9,323,826	2.15	
Taxes and license fees	867,178	0.20	
Total depreciation ($1,000)	2,522,293	0.58	
Net Profit Before Income Taxes	**45,972,170**	**10.62**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Residential Building Construction. Sector 23, EC0723I1: 236220 (Commercial Building Construction. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2017.

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APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

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APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

6B.1 INTRODUCTION

Since 2004, the U.S. Department of Energy (DOE) has applied the incremental markup approach to estimate the increase in final product price of high-efficiency products as a function of the increase in manufacturing cost.[1] In this appendix we calculate the change in final consumer prices due to minimum efficiency standards, focusing on a standard economic model of the air-conditioning and heating equipment (ACHE) wholesale industry. The model examines the relationship between the marginal cost to distribute and sell equipment and the final consumer price in this industry. The model predicts that the impact of a standard on the final consumer price is conditioned by its impact on marginal distribution costs. For example, if a standard raises the marginal cost to distribute and sell equipment a small amount, the model predicts that the standard will raise the final consumer price a small amount as well. Statistical analysis suggest that standards do not increase the amount of labor needed to distribute equipment the same employees needed to sell lower efficiency equipment can sell high efficiency equipment. Labor is a large component of the total marginal cost to distribute and sell air-conditioning and heating equipment. We infer from this, that standards have a relatively small impact on ACHE marginal distribution and sale costs. Thus, our model predicts that a standard will have a relatively small impact on final ACHE consumer prices. Our statistical analysis of U.S. Census Bureau wholesale revenue tends to confirm this model prediction. Generalizing, we find that the ratio of manufacturer price to final consumer price prior to a standard tends to exceed the ratio of the change in manufacturer price to the change in final consumer price resulting from a standard. The appendix expands our analysis through a typical distribution chain for commercial and residential air-conditioning and heating equipment. Under this approach, DOE applies a lower markup than the average markup to the incremental cost of higher-efficiency products, relative to the baseline product. The approach is described in detail in chapter 6.

DOE's incremental markup approach is based on the widely accepted economic view that prices closely reflect marginal costs in competitive markets and in those with some degree of concentration. Evaluating industry data in IBISWorld suggests that most of the industries relevant to heating, ventilation, and air conditioning (HVAC) wholesalers and contractors are considered to have low market concentration, high and increasing market competition and low to medium barriers to entry (see Table 6B.1.1).[2]

Table 6B.1.1 Competitive Environment of HVAC Sectors

Sector	Industry Concentration	Competition	Barriers to Entry
Home builders	Low	High and increasing	Low and steady
Commercial building construction	Low	High and steady	Medium and steady
Heating & air-conditioning contractors	Low	High and increasing	Medium and steady
Heating & air-conditioning wholesaling	Low	High and steady	Medium and increasing

Examining gross margin and price data in HVAC wholesale industry over time, DOE finds that both gross margins and prices did not demonstrate any persistent trend; thus, this set of historical data has no bearing on firm markup behavior under product price increases, such as may occur as a result of standards.

To investigate markup behavior under product price increases, DOE evaluated time series gross margin data from three industries with rapidly changing input prices – the LCD television retail market, the U.S. oil and gasoline market, and the U.S. housing market. Additionally, DOE conducted an in-depth interview with an HVAC consultant who represents many individual contractors in the industry.

6B.2 MARGIN TRENDS UNDER PRICE VOLATILITY

Heating, Air-Conditioning and Refrigeration Distributors International (HARDI) published annual profit report with aggregated financial and operating data of its participating firms in HVAC wholesale industry.[3] DOE evaluated the percent gross margins[a] and sales revenue per shipment received (as a proxy for average HVAC wholesale prices) reported from 1999 to 2012 for typical HARDI distributors.[b] As shown in Figure 6B.2.1, average HVAC wholesaler prices have experienced some fluctuations during this period of time, but the overall wholesale price trend is relatively stable, with a price increase of four percent from 1999 to 2012.

However, the existence of constant percent margin over time is not sufficient to identify an industry's markup practice without considering the underlying input price changes during the same period. If the prices have been relatively constant, the incremental markup approach will arrive at the same result as applying constant margin. In fact, the average HVAC wholesale prices have been relatively stable over time;[c] hence, the historically constant percent margins do not necessarily imply a constant percent margin in the future, especially in the case of increased input prices due to standards (Figure 6B.2.1).

[a] Percent gross margin is defined as gross margin in percentage of sales revenue.
[b] The typical distributors are the firms with median financial results among all participating firms.
[c] In 2005 the HVAC market experienced a brief 15-percent price rise. The HVAC price increase may be attributed to the 2006 Central Air-Conditioner and Heat Pump Standard. Percent gross margins declined slightly at this time.

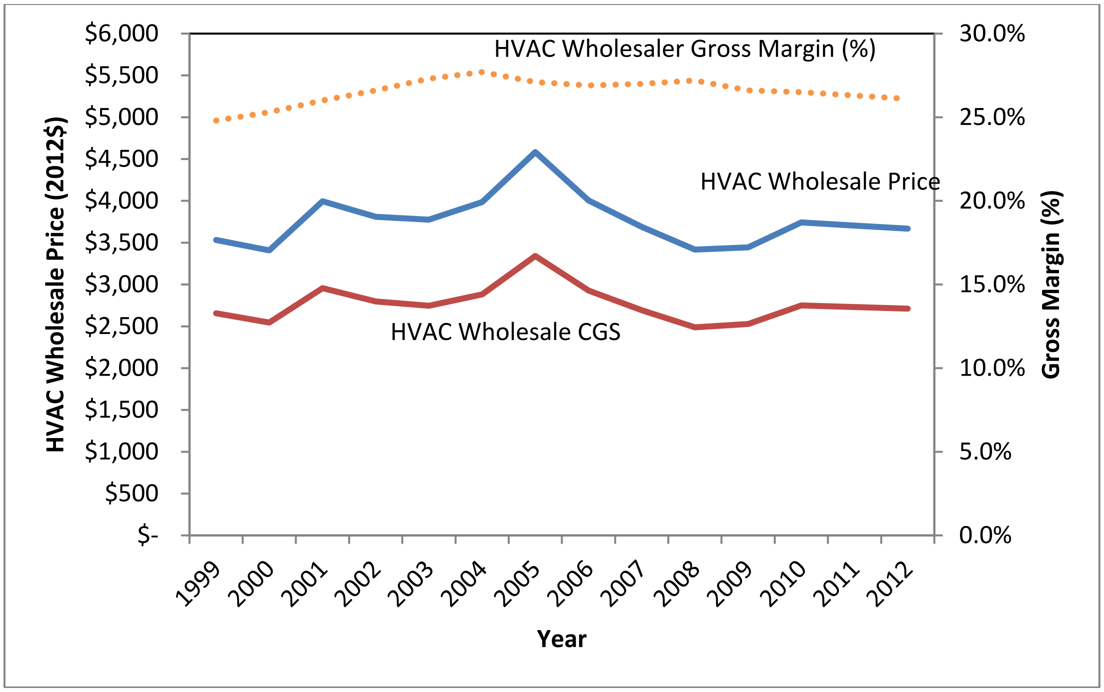

Figure 6B.2.1 HVAC Wholesale Prices, Cost of Goods Sold and Gross Margins

As historical data in HVAC wholesale markets cannot be used to address the question of margins under a price shock, DOE looked to other publicly available data for markets of a single product that have experienced noticeable price changes, evaluating the prevalence of fixed percent gross margins.

To replicate the theorized conditions of efficiency standard implementation, DOE would ideally analyze a household durable that has experienced a consistent rise in price, such as may occur as a result of standards. The LCD television retail market, on the other hand, is a market with a consistently downward price trend since 2007. The material costs and retail prices of LCD televisions have both dropped substantially over this period. At the same time, average retailer gross margins have decreased from 25 percent in 2007 to only 6 percent in late 2014. Under the change in input price (*i.e.*, cost of goods sold (CGS)), retailers did not maintain constant percent gross margins (Figure 6B.2.2).[d]

[d] LCD television data from DisplaySearch, a market research company affiliated with NPD Group.

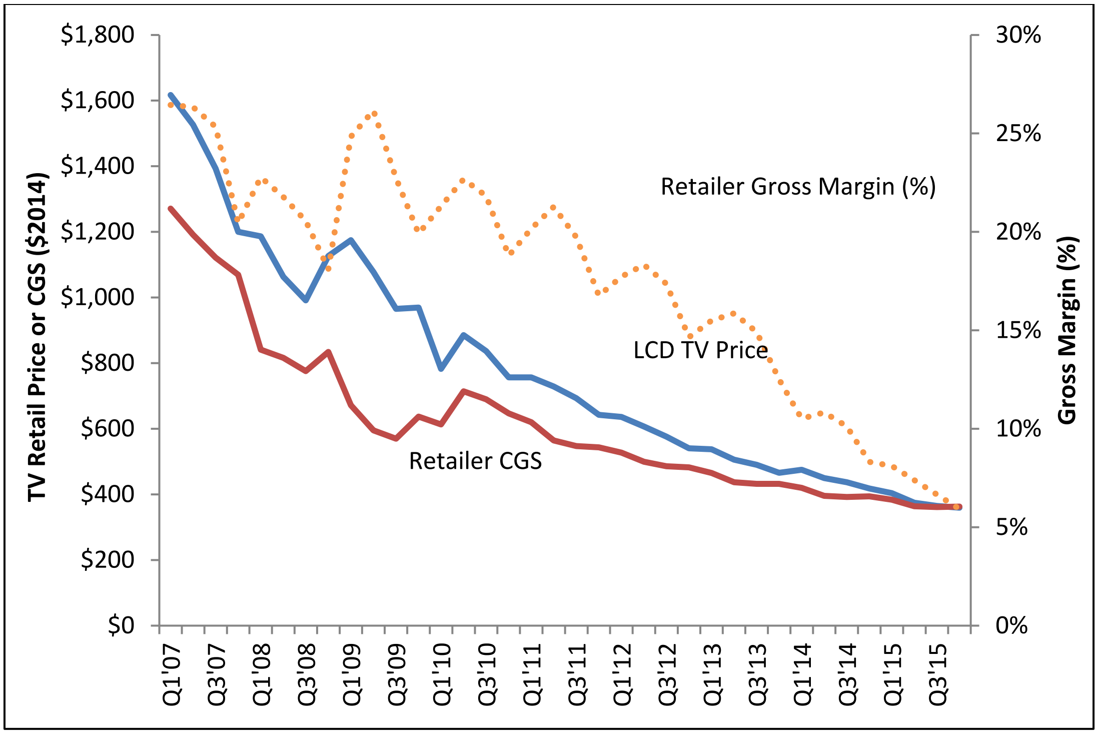

Figure 6B.2.2 LCD TV Prices, Cost of Goods Sold and Gross Margins

DOE also analyzed margin behavior in markets with upward price trends to test the prevalence of fixed percent gross margins. U.S. imported crude oil prices rose by $2.50 per gallon from 1995 to 2008, but the percent retail gross margins have decreased during the same period of time (Figure 6B.2.3).[4]

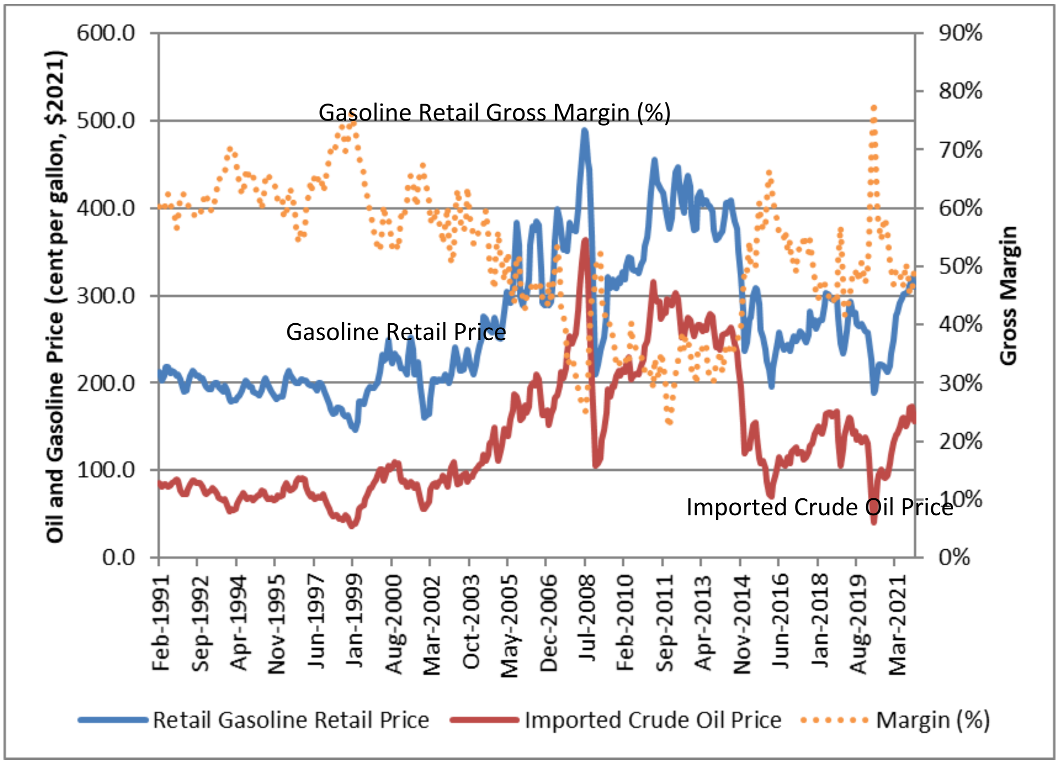

Figure 6B.2.3 Oil and Gasoline Price, Gross Margin

The U.S. inflation-adjusted median home sales prices and the costs of selling, measured by home sales price minus agent's commission fee, have increased substantially from 1991 to 2005. The percent gross margin in the housing market (*i.e.*, commission rate), however, has declined by 15 percent over this period.[e] (Figure 6B.2.4)[6,7,8,9] Similar pattern was found during the period from 2011 to 2018. In short, fixed percent gross margins are not observed in this market with increasing costs.

[e] Federal Trade Commission and the U.S. Department of Justice published a report, titled "Competition in the Real Estate Brokerage Industry", which provides extensive literature review on the topic of housing prices and brokerage commission fee, and the empirical evidences are consistent with our findings.[5]

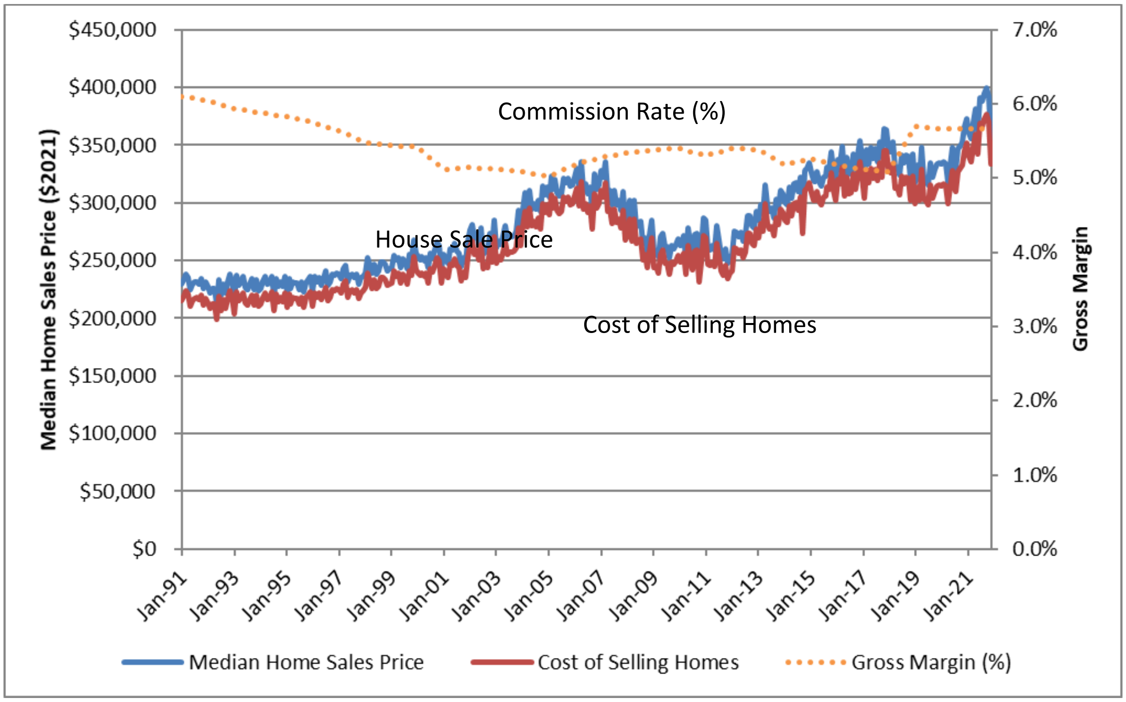

Figure 6B.2.4 House Sales Price, Costs of Selling Homes, and Realtor Commission (%)

After examining price and gross margin data in various markets, the results indicate that prices could go up or down in different circumstances, but in no case are percent gross margins observed to remain fixed over time. Hence, DOE does not expect that firms can sustain on applying constant markups on incremental costs of more efficient products after standards.

6B.3 SUMMARY OF CONSULTANT INTERVIEW

To gain insight into contractor markup determination, DOE interviewed an experienced consultant who specializes in the HVAC contracting field (see consultant interview in section 6B.4).[f] Because the incremental markup is applied in a very specific analytical situation where the input cost increases due to the standard while other costs remain the same, it was necessary to carefully craft the interview to accurately convey the concept. The list of key questions asked of the consultant includes the following points:

1. *Assuming the HVAC equipment price increases while the other costs remain constant (no change in labor, material, and operating costs), are contractors still able to keep the same markup over time as before?*
2. *Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?*

[f] Michael Stone is co-founder of Construction Programs & Results, Inc. (www.markupandprofit.com), has more than five decades of experience in the building and remodeling industry, and is the author of Markup and Profit; A Contractor's Guide (1998), Profitable Sales: A Contractor's Guide (2007), and, Markup and Profit; A Contractor's Guide Revisited (2012).

3. *If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?*

The consultant responded as follows:

1. *Initially, contractors will attempt to use the same markup after the increase in input cost occurs, but, assuming there is no increase in other costs, "they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated."*
2. *Any increase in profit following an input cost increase is likely to be short-lived. "There are too many pressures on contractors to lower their prices for various reasons… We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago."*
3. *Contractor profit margins and markups are typically reevaluated every three to six months; this limits the timeframe in which higher-than-sustainable profits are likely to persist.*

The consultant's responses provide real-world evidence indicating that HVAC contractors aim to maintain fixed percent markups, but market pressures force them to reevaluate and adjust markups over time to stay competitive. This empirical phenomenon reinforces the underlying theory and assumptions inherent in the incremental markup approach used in DOE's post-standard price projections. While the consultant speaks specifically to the practices of HVAC contractors, his descriptions of firm response to cost increase over time in a competitive environment can be logically extended to wholesalers and retailers as well. DOE concludes that the combined evidence of changing percent gross margins across industries with cost changes and the support of the industry consultant justify the use of the incremental markup approach.

6B.4 CONSULTANT INTERVIEW REPORT

In this section, the original responses from consultant regarding markup practice in construction industry is presented as a supplementary material supporting the use of incremental markup when estimating the consumer product price of more efficient products.

To: Lawrence Berkeley National Laboratory
From: Michael Stone, Construction Programs & Results, Inc.
Date: January 26, 2015
Re: Supplementary questions on contractor markups

After a new energy efficiency standard is in place, the equipment prices generally go up as less efficient (cheaper) ones are eliminated on the market by new standard. The questions below are intended to help us understand the impact of increased equipment prices on contractors' markup practices and profitability. That is, how contractors react to this change in equipment price while the other costs remain constant.

(1) Assuming the equipment price increases while the other costs remain constant (no change in labor, material and operating costs), are contractors still able to keep the same markup over time as before?

Michael Stone (Michael): *Yes and no. The contractors will attempt to use the same markup over time, but, assuming no increase in other costs, they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated.*

Keep in mind the numbers and our answer assume a "pure" company; one that currently only installs the lower efficiency units and that in the future will only install the higher efficiency units. They don't perform any other service work or install any other equipment. Those companies don't exist in real life. So it's most likely that on individual sales, if under pressure, the contractor might choose to reduce their markup because they recognize the equipment price increase without other related cost increases. The markup change will happen when the company's finances are reviewed, and the equipment cost increase will be only one factor in the adjustment.

(2) Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?

Michael: *Probably not. There are too many pressures on contractors to lower their prices for various reasons. Unless building owners suddenly have more money to spend and consider the work on their building valuable enough to pay what it's worth, profitability will stay the same.*

We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago.

(3) If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?

Michael: *Generally speaking, 3-6 months.*

(4) For commercial contractors, is the market as competitive as for residential contractors? Is there a significant difference in their ability to maintain a fixed markup between commercial and residential contractors? If so, please elaborate the differences.

Michael: *There are so many variations in how commercial contractors operate, and the market is considerably different than residential. But it is as competitive.*
Many of them get jobs because of their connections. They do a lot of marketing and schmoozing, promoting themselves to buyers. This enables them to get jobs easier. If they have long-time relationships with general contractors who are primarily concerned with getting a job well-built with few problems, they can have an easier time maintaining a fixed markup. If they have long-time relationships with general contractors who are more concerned about getting the job built at the lowest possible price, they might choose to cut their price to get jobs.
Others get jobs by competing to be the lowest price. If they have relationships and can influence the bid process, they might have a bid that's written with them in mind, making it easier for them to be low bid and still maintain a reasonable markup on the job. Other contractors just shoot to be the lowest bid and have a tough time being profitable (ie, no, they don't maintain a fixed markup).

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APPENDIX 7A. HOUSEHOLD AND BUILDING VARIABLES

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APPENDIX 7A. HOUSEHOLD AND BUILDING VARIABLES

7A.1 INTRODUCTION

U.S. Department of Energy (DOE) created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s 2015 Residential Energy Consumption Survey (RECS 2015)[1] and DOE's Energy Information Administration (EIA)'s 2012 Commercial Building Energy Consumption Survey (CBECS 2012)[2] using Microsoft ACCESS. DOE used this RECS 2015 subset in the life-cycle cost (LCC) analysis of the consumer pool heaters rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values.

The RECS consists of three parts:

- Personal interviews with households for information about energy used, how it is used, energy-using appliances, structural features, energy efficiency measures, and demographic characteristics of the household.
- Telephone interviews with rental agents for households that have any of their energy use included in their rent. This information augments information collected from those households that may not be knowledgeable about the fuels used for space heating or water heating.
- Mail questionnaires sent to energy suppliers (after obtaining permission from households) to collect the actual billing data on energy consumption and expenditures.

For the entire RECS 2015 dataset, refer to https://www.eia.gov/consumption/residential/data/2015/index.php?view=microdata.

For the entire CBECS 2012 dataset, refer to http://www.eia.gov/consumption/commercial/data/2012/index.cfm?view=microdata.

DOE derived seven separate pool heater samples for each pool heater market type (including pool heaters used in either residential or commercial applications)[a] as follows:

1) Pool heaters in single family homes that serve a swimming pool only,
2) Pool heaters in single family homes that serve both a swimming pool and spa,[b]

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[a] Standards established for pool heaters apply to any gas-fired and electric pool heater regardless of input capacity. DOE limited its energy use analysis to smaller commercial-sized pool heaters similar to the ones found in residential applications, because it has limited data on the number of large commercial-sized pool heaters and their energy use.
[b] RECS 2015 uses the term hot tub instead of spa. When a household has a pool heater and spa heater of the same fuel, RECS 2015 does not provide information about whether the pool heater is used for both. DOE assumes that in this case, a single pool heater is used to heat both the pool and spa.

3) Pool heaters in single family homes that serve a spa only,[c]
4) Pool heaters in single-family community swimming pools or spas,
5) Pool heaters in multi-family community swimming pools or spas,
6) Pool heaters in indoor commercial swimming pools or spas, and
7) Pool heaters in outdoor commercial swimming pools or spas.

7A.2 RESIDENTIAL SAMPLE DETERMINATION USING RECS DATA

The subset of RECS 2015 records used in the analysis met all of the following criteria:

- The household had a swimming pool or spa.
- A pool heater was used to heat pool or spa water.
- The pool heater used gas or electricity as a heating fuel.

The RECS 2015 weighting indicates how commonly each household configuration occurs in the general population.

DOE used RECS 2015 to establish a sample of single-family homes that use an electric or gas-fired pool heater in a pool heater market type 1, 2, and 3 (Table 7A.2.1 and Table 7A.2.2). RECS 2015 includes energy-related data from more than 5,600 housing units that represent almost 118.2 million occupied households. RECS 2015 includes information such as the household or building owner demographics, fuel types used, months swimming pool used in the last year, energy consumption and expenditures, and other relevant data. DOE's calculation of the annual energy use for pool heaters in market types 1, 2, and 3 relied directly on energy consumption data from RECS 2015 as shown in chapter 7 to calculate the pool heater heating load.

Based on manufacturer input, DOE adjusted the sample weight for electric pool heaters used in spas only (pool heater market type 3) to 1.5 percent of the original RECS weights.[d] Similarly, for gas-fired pool heaters used in spas only (pool heater market type 3), DOE adjusted the sample weight to 50 percent of the original RECS weights based on historical shipments model estimates (see chapter 9 for more details). Finally, DOE used 2022 Pkdata by state, RECS 2020 by state,[3] and CBECS 2018 data by census division[4] to weight the sample to the most recent data available.

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[c] For electric pool heater sample, DOE only considered a small fraction of large spas that require a pool heater large than 11 kW. For this NOPR, The fraction of spas with an electric pool heater larger than 11 kW was determined based on 2022 Pkdata.

[d] Manufacturers stated that the great majority of electric pool heaters used in spas are electric resistance pool heaters at or below 11 kW input capacity, which falls outside the scope of this rulemaking. For this analysis, DOE did not perform energy conservation standards analysis for electric spa heaters which are defined to have a rated output capacity of 11 kW or less and are factory- or field-assembled within the envelope of a spa, hot tub, or pool. Note that DOE identified the 11 kW threshold as being a typical output capacity below which electric resistance heaters are integrated in spas, hot tubs, or pools. See chapter 5 for further details

Table 7A.2.1 Selection of RECS 2015 Records for Pool Heaters Market Type 1, 2, 3, 4, and 5 Subsamples

Pool Heater Market Type	Algorithm	Pool Heater Type	No. of Records	DOE Sample Weight *(million)**
1) Pool heaters in single family homes that serve a swimming pool only	• House has a swimming pool = Yes • Swimming pool has pool heater = Yes • Pool heater fuel type = Gas[e] or Electricity • If the house has a spa, is the spa heater of the same fuel type as the pool heater = No	EPH	24	0.083
		GPH	33	0.161
2) Pool heaters in single family homes that serve both a swimming pool and spa	• House has a swimming pool = Yes • Swimming pool has pool heater = Yes • House has a spa = Yes • Pool heater fuel type = Gas or Electricity • The spa heater is of the same fuel type as the pool heater = Yes	EPH	10	0.024
		GPH	38	0.105
3) Pool heaters in single family homes that serve a spa only	• House has a spa = Yes • Spa heater fuel type = Gas or Electricity • If the house has a swimming pool with a pool heater, is the pool heater of the same fuel type as the spa heater = No	EPH	201	0.011
		GPH	59	0.082
4) Pool heaters in community pools (single-family)	• Single Family = Yes • Has pool or spa heater = No	EPH	2827	0.001
		GPH	3295	0.006
5) Pool heaters in community pools (multi-family)	• Multi-Family = Yes • Has pool or spa heater = No	EPH	927	0.003
		GPH	1030	0.021

* RECS2015 weight for number of households is the same as the DOE pool heater sample weight except for pool heater market type 3.

** DOE's pool heater sample weight has been adjusted as follows: 1.5% for EPHs and 50% for GPHs of the RECS 2015 household weight. The final weight is also adjusted to matches number of pool heater shipments (see chapter 9).

Table 7A.2.2 Criteria for Selection of Pool Heaters Household Sample

By Pool Type	Selection Criteria Using RECS 2015 Variables
1) Pool Only	SWIMPOOL = 1 POOL = 1 FUELPOOL = 1, 2, or 5 (≠FUELTUB = 1, 2, or 5)
2) Pool + Spa	SWIMPOOL = 1 POOL = 1 RECBATH = 1 FUELPOOL = 1, 2, or 5 (=FUELTUB = 1, 2, or 5)
3) Spa Only	RECBATH = 1 FUELTUB = 1, 2, or 5 (≠FUELPOOL = 1, 2, or 5)

[e] Gas includes natural gas and propane (or "LPG").

7A.3 COMMERCIAL SAMPLE DETERMINATION USING CBECS AND RECS DATA

As mentioned before, the commercial building sample consists of four parts: 1) community pool heaters in single family household communities; 2) community pool heaters in multi-family household communities; 3) other commercial applications (indoor swimming pools); 4) other commercial applications (outdoor swimming pools).

There is limited data on the building sample associated with pool heaters in commercial applications with the exception of gas-fired and electric pool heaters in indoor swimming pools listed in CBECS 2012. The subset of CBECS 2012 records used in the analysis for indoor installation met all of the following criteria:

- The building had an indoor swimming pool.
- A pool heater was used to heat pool.
- The pool heater used gas or electricity as a heating fuel.

For sample subset 6 (pool heaters used in indoor swimming pools in commercial applications), CBECS 2012 records were used. CBECS 2012 includes energy-related data from more than 6,720 commercial buildings that represent almost 5.6 million buildings. CBECS 2012 includes information such as if a building has an indoor swimming pool and the energy source for the pool heater. See Table 7A.3.1 and Table 7A.3.2. Finally, DOE used 2022 Pkdata by state, RECS 2020 by state,[3] and CBECS 2018 data by census division[4] to weight the sample to the most recent data available.

Table 7A.3.1 Selection of CBECS 2012 Records for Pool Heaters Market Type 6 and 7 Subsample

Pool Heater Market Type	Algorithm	Pool Heater Type	No. of Records	No. of U.S. Households Represented *(million)**
6) Pool heaters in indoor commercial swimming pools or spas	• Building has an indoor swimming pool = Yes • Pool heater fuel type = Gas or Electricity	EPH	26	0.002
		GPH	90	0.015
7) Pool heaters in indoor commercial swimming pools or spas	• Building activity types could have an outdoor swimming pool = Yes	EPH	1751	0.010
		GPH	1483	0.002

* DOE's pool heater sample weight has been adjusted to match 2022 Pkdata regarding fraction of commercial indoor versus outdoor swimming pools.

Table 7A.3.2 Criteria for Selection of Pool Heaters Household Sample

By Pool Type	Selection Criteria Using CBECS 2012 Variables
4) Pool + Spa	POOL = 1 HTPOOL = 1 POOLSRC = 1, 2, or 4

Neither RECS 2015 nor CBECS 2012 have sufficient household or building information to distinguish other sample subsets (numbers 4, 5, and 7), as they do not include information about pools for common areas in multi-family residences and complexes or outdoor pools in commercial buildings. To determine the market share and sample for these sample subsets DOE used a combination of sources including RECS 2015, CBECS 2012, 2009 American Housing Survey (AHS),[5] 2011 AHS,[6] and 2022 Pkdata.[7] For these three commercial subsamples DOE used the total CBECS and RECS weights of households and buildings by Census division to estimate the weight of these subsamples by region as follows:

1. For community pool heaters in single-family and multi-family household communities: DOE assumed that on average, there are about 250 housing units per shared community pool. DOE estimated that 44 percent of single family homes and 40 percent for multi-family homes live in communities with recreational facilities such as a swimming pool based on 2009 AHS. DOE assumed that half of these have a swimming pool (the weighting of which varies proportionally to the fraction of swimming pools in single family homes per census division, see Table 7A.3.3). In addition, DOE assumed that the fraction of single-family and multi-family community swimming pool with pool heaters is proportional to the fraction in single-family homes by Census division.
2. For other commercial application swimming pools: DOE assumed that only commercial buildings that are listed in CBECS 2012 with the primary activities as public assembly, education, health care, and lodging would have a pool heater. The building weights where adjusted based on 2022 PK Data data regarding the fraction of swimming pools by building activity adjusted the fraction of pools going to each primary activity (Table 7A.3.4). Similar to community pools, DOE assumed that the fraction of buildings with swimming pools and the fraction with a pool heaters is similar to that in single family homes by Census division (see Table 7A.3.3). Table 7A.3.4 presents the resulting commercial subsample by building activity/sector and by pool heater product class.

Table 7A.3.3 Fraction of Single-Family Households with a Pool Heater and Fraction with a Swimming Pool by Census Division (RECS 2015 Data)

Census Div.	Fraction of Electric Pool Heaters	Fraction of Gas-fired Pool Heaters	Fraction of Swimming Pools*
1	66%	34%	15%
2	25%	54%	14%
3	9%	57%	8%
4	0%	100%	2%
5	43%	37%	14%
6	63%	37%	9%
7	18%	82%	11%
8	15%	72%	9%
9	20%	65%	9%

* For community pools, DOE assumed that the fraction of communities with a recreational facility that has a swimming pool is 50 percent, or 5 times more than the 10 percent fraction in single-family homes, so DOE multiplied these fractions by 5 to apply to the community pool weighting.

Table 7A.3.4 Pool Heater Sample By Commercial Sector

Building Activity/Sector	Elec	Gas	All
Lodging	25.1%	23.0%	23.3%
Multi-Family Pools	45.0%	38.7%	39.6%
Community Pools	13.2%	11.6%	11.8%
Public Assembly	13.2%	19.8%	18.9%
Education	2.2%	5.0%	4.6%
Health Care	1.2%	1.8%	1.7%

Table 7A.3.5 summarizes the pool heater subsamples and the estimated fraction of shipments by subsample type. Table 7A.3.6 summarizes the pool subsamples by census division, residential and commercial sectors, and by pool heater product class.

Table 7A.3.5 Fraction of Electric and Gas-Fired Pool Heaters by Pool Heater Market

Pool Heater Market Type ID	Description of Pool Heater Market Type	Fraction of Electric Pool Heaters (Percent)	Fraction of Gas-fired Pool Heaters (Percent)
1	Single Family with Pool Heater Serving Swimming Pool Only	65.9	40.3
2	Single Family with Pool Heater Serving Swimming Pool + Spa	19.0	26.4
3	Single Family with Pool Heater Serving Spa Only	8.8	20.4
4	Community Pools or Spas (Single-Family)	0.8	1.5
5	Community Pools or Spas (Multi-Family)	2.8	5.1
6	Commercial Indoor Pools and Spas	1.4	3.8
7	Commercial Outdoor Pools and Spas	1.3	2.5

Table 7A.3.6 Fraction of Pool Heaters by Census Division

Census Division	Electric Pool Heaters		Gas-fired Pool Heater	
	Residential	Commercial	Residential	Commercial
New England	7%	17%	2%	8%
Middle Atlantic	9%	16%	12%	17%
East North Central	6%	3%	15%	13%
West North Central	1%	3%	5%	4%
South Atlantic	42%	32%	15%	14%
East South Central	8%	10%	2%	3%
West South Central	7%	7%	16%	17%
Mountain	6%	2%	10%	8%
Pacific	16%	10%	25%	16%

7A.4 RECS 2015 DATABASE VARIABLE RESPONSE CODES

Table 7A.4.1 lists the variables used in the analysis.

Table 7A.4.1 List of RECS 2015 Variables Used for Electric Pool Heaters

Variable	Description
Location Variables	
DIVISION	Census Division
HDD65	Heating degree days in 2015, base temperature 65F
CDD65	Cooling degree days in 2015, base temperature 65F
Household Characteristics Variables	
NWEIGHT	Final sample weight
DOEID	Unique identifier for each respondent
TYPEHUQ	Type of housing unit
MONEYPY	2015 gross household income
NHSLDMEM	Number of household members
Seniors*	Number of household members age 65 or older
SWIMPOOL	Has a swimming pool
POOL	Has a heated swimming pool
FUELPOOL	Fuel used for heating swimming pool
FUELPOOL	Pool heater fuel
RECBATH	Does the home have a heated hot tub or spa?
MONPOOL	Months swimming pool used in the last year
MONTUB	Months hot tub used in the last year
ADJUSTED FUEL USE	Calculated Pool Heater energy use

* Not part of RECS 2015 variables.

Table 7A.4.2 provides the response codes for the RECS 2015 variables used in the electric pool heater sample.

Table 7A.4.2 Definitions of RECS 2015 Variables Used in Life-Cycle Cost Analysis

Variable	Response Codes	
DIVISION	1	New England Census Division (CT, MA, ME, NH, RI, VT)
	2	Middle Atlantic Census Division (NJ, NY, PA)
	3	East North Central Census Division (IL, IN, MI, OH, WI)
	4	West North Central Census Division (IA, KS, MN, MO, ND, NE, SD)
	5	South Atlantic Census Division (DC, DE, FL, GA, MD, NC, SC, VA, WV)
	6	East South Central Census Division (AL, KY, MS, TN)
	7	West South Central Census Division (AR, LA, OK, TX)
	8	Mountain North Sub-Division (CO, ID, MT, UT, WY)
	9	Mountain South Sub-Division (AZ, NM, NV)
	10	Pacific Census Division (AK, CA, HI, OR, WA)
DOEID	00001 - 12083	Unique identifier for each respondent
HDD65	Heating degree days in 2009, base temperature 65F	
MONEYPY	1	Less than $20,000
	2	$20,000 - $39,999
	3	$40,000 - $59,999
	4	$60,000 to $79,999
	5	$80,000 to $99,999

Variable	Response Codes
	6 $100,000 to $119,999 7 $120,000 to $139,999 8 $140,000 or more
NHSLDMEM	0 - 20 Number of household members
NWEIGHT	Final sample weight
Seniors*	0 to 1 Value adjusted the weight of the sample
TYPEHUQ	1 Mobile Home 2 Single-Family Detached 3 Single-Family Attached 4 Apartment in Building with 2 - 4 Units 5 Apartment in Building with 5+ Units
SWIMPOOL	0 No 1 Yes -2 Not Applicable
MONPOOL	0 - 12 Months swimming pool used in the last year -2 Not applicable
POOL	0 No 1 Yes -2 Not Applicable
FUELPOOL	1 Natural gas from underground pipes 2 Propane (bottled gas) 3 Fuel oil/kerosene 5 Electricity 8 Solar 21 Some other fuel -2 Not applicable
RECBATH	1 Yes 0 No
MONTUB	0 - 12 Months hot tub used in the last year -2 Not applicable
FUELTUB	1 Natural gas from underground pipes 2 Propane (bottled gas) 3 Fuel oil/kerosene 5 Electricity 8 Solar 21 Some other fuel -2 Not applicable

* Not part of RECS 2015 variables.

7A.5 CBECS 2012 DATABASE VARIABLE RESPONSE CODES

Table 7A.5.1 lists the variables used in the analysis.

Table 7A.5.1 CBECS 2012 Variables Used for Pool Heaters in Commercial Buildings

Variable	Description
Location Variables	
CENDIV	Census division
HDD65	Heating degree days (base 65)
CDD65	Cooling degree days (base 65)
Household Characteristics Variables	
PUBID	Building identifier
ADJWT	Final full sample building weight
PBA	Principal building activity
OWNER	Owner
POOL	Indoor pool
HTPOOL	Heated indoor pool
PLSRC	Energy source used to heat pool

Table 7A.5.2 provides the response codes for all CBECS 2012 variables used in the commercial warm air furnace sample.

Table 7A.5.2 CBECS 2012 Variable Response Codes

Variable	Response Codes
PUBID	Unique identifier for each respondent
ADJWT	Final sample weight
CENDIV	01 New England 02 Middle Atlantic 03 East North Central 04 West North Central 05 South Atlantic 06 East South Central 07 West South Central 08 Mountain 09 Pacific
HDD65	Heating degree days in 2003, base temperature 65F
PBA	01 Vacant 02 Office 04 Laboratory 05 Nonrefrigerated warehouse 06 Food sales 07 Public order and safety 08 Outpatient health care 11 Refrigerated warehouse 12 Religious worship 13 Public assembly 14 Education 15 Food service 16 Inpatient health care 17 Nursing 18 Lodging 23 Strip shopping mall

Variable	Response Codes
	24 Enclosed mall 25 Retail other than mall 26 Service 91 Other
OWNER	01 Property management company 02 Other corporation/partnership/LLC 03 Religious organization 04 Other non-profit organization 05 Privately-owned school 06 Individual owner 07 Other nongovernment owner 08 Federal government 09 State government 10 Local government
POOL	0 = NO 1 = YES
HTPOOL	0 = NO 1 = YES
PLSRC	1=Electricity 2=Natural gas 3=Fuel oil/diesel/kerosene 4=Bottled gas/LPG/Propane 5=Solar 6=Some other energy source

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APPENDIX 7B. DETERMINATION OF ENERGY USE IN THE LCC ANALYSIS

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7B.1 INTRODUCTION

DOE modified the method stipulated in the federal pool heater test procedure[1] to calculate the annual energy consumption at the considered energy efficiency levels for each household to account for actual field conditions. To estimate the annual energy consumption of pool heaters, DOE used a number of sources including Energy Information Administration's (EIA) 2015 Residential Energy Consumption Survey (RECS 2015)[2] and EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012),[3] a Consortium for Energy Efficiency (CEE) report, a Brookhaven National Laboratory report,[4,5] and 2022 Pkdata.[6] Section 7B.2 summarizes the determination of the annual gas and electricity consumption for EPHs and GPHs. The rest of the appendix provides additional information on some of the inputs.

7B.2 ANNUAL GAS AND ELECTRICITY CONSUMPTION CALCULATIONS FOR POOL HEATERS

In the pool heater test procedure, determines the annual energy consumption of pool heaters (E_F) is calculated as follows:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_{PR} + (8760 - POH) \times Q_{off,R}$$

Eq. 7B.1

Where:

BOH = average number of burner operating hours, h,
POH = average number of pool operating hours, h,
Q_{IN} = rated fuel energy input as defined according to section 2.10.1 or section 2.10.2 of ANSI, Z21.56 as appropriate.
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, = (Q_P/1 h),
Q_P = energy consumption of continuously operating pilot light, if employed, Btu,
8760 = number of hours in one year,
$Q_{off,R}$ = average off mode fossil fuel energy consumption rate = Q_{off}/(1 h), and
Q_{off} = off mode energy consumption.

In chapter 7 of this TSD, the equation is summarized and expanded as follows:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_{PR} + (8760 - POH) \times Q_{off,R} \times PH_{off}$$

Eq. 7B.2

Where:

BOH = average number of burner (active mode) operating hours per year, h/yr,

POH = average number of pool operating hours per year, h/yr,
Q_{IN} = rated fuel energy input, kBtu/h,
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, kBtu/h,
8760 = number of hours in one year, h,
$Q_{off,\,R}$ = average off mode fossil fuel energy consumption rate, kBtu/h, and
$PH_{off,}$ = factor to take into account fraction of pool heaters that are "winterized" and do not have any off-mode energy use, value is 0 if the pool heater is "winterized" and 1 otherwise.

In the DOE test procedure, the average annual electrical energy consumption (E_{AE}) for pool heaters is given by:

$$E_{AE} = BOH \times PE + (POH - BOH) \times P_{W,SB} + (8760 - POH) \times P_{W,OFF}$$

Eq. 7B.3

Where:

$E_{AE,active}$ = electrical consumption in the active mode,
$E_{AE,standby,off}$ = auxiliary electrical consumption in the standby mode and off mode,
$PE = 2E_c$, for fossil fuel-fired heaters tested according to section 2.10.1 of ANSI Z21.56 and for electric resistance pool heaters, Btu/h,
= 3.412 PE_{rated}, for fossil fuel-fired heaters tested according to section 2.10.2 of ANSI Z21.56, Btu/h,
= $E_{c,HP}$ * ($60/t_{HP}$), for electric heat pump pool heaters, Btu/h,
E_c = electrical consumption in Btu per 30 min. This includes the electrical consumption (converted to Btus) of the pool heater and, if present, a recirculating pump during the 30-minute thermal efficiency test. The 30-minute thermal efficiency test is defined in section 2.10.1 of ANSI Z21.56 for fossil fuel-fired pool heaters and section 9.1.4 of ASHRAE 146 for electric resistance pool heaters,
2 = conversion factor to convert unit from per 30 min. to per h,
PE_{rated} = nameplate rating of auxiliary electrical equipment of heater, Watts,
$E_{c,HP}$ = electrical consumption of the electric heat pump pool heater (converted to equivalent unit of Btu), including the electrical energy to the recirculating pump if used, during the thermal efficiency test, as defined in section 9.1 of ASHRAE 146, Btu,
t_{HP} = elapsed time of data recording during the thermal efficiency test on electric heat pump pool heater, as defined in section 9.1 of ASHRAE 146, in minutes,
BOH = average number of burner operating hours, h,
POH = average number of pool operating hours, h,
$P_{W,SB}$ (Btu/h) = electrical energy consumption rate during standby mode expressed in Btu/h = 3.412 $P_{W,SB}$, Btu/h,
$P_{W,OFF}$ (Btu/h) = electrical energy consumption rate during off mode expressed in Btu/h = 3.412 $P_{W,OFF}$, Btu/h.

In chapter 7 of this TSD, the equation is summarized and expanded as follows:

$$E_{AE} = BOH \times PE + (POH - BOH) \times P_{W,SB} + (8760 - POH) \times P_{W,off} \times PH_{off} + Adj_{pump\_use}$$

Eq. 7B.4

Where:

BOH = average number of burner (active mode) operating hours, h/yr,
POH = average number of pool operating hours, h/yr,
PE = electrical consumption rate in the active mode, kW,
$P_{W,SB}$ = electrical energy consumption rate during standby mode, kW,
8760 = number of hours in one year, h,
$P_{W,off}$ = electrical energy consumption rate during off-mode, kW,
$PH_{off,}$ = factor to take into account fraction of pool heaters that are "winterized" and do not have any off-mode energy use, value is 0 if the pool heater is "winterized" and 1 otherwise, and
Adj_{pump_use} = adjustment to take into account differences in pump energy consumption between the different efficiency levels, kWh.

Not that for EPHs, PE is equal to the input capacity (Q_{IN}), which varies by efficiency level and is calculated as follows:

$$Q_{IN} = \frac{Q_{out}}{E_t}$$

Eq. 7B.5

Where:

Q_{out} = output capacity of the pool heater and
E_t = thermal efficiency, percent.

7B.3 DETERMINING POOL HEATER ANNUAL LOAD USING RECS ENERGY USE ESTIMATES

Based on the DOE test procedure the average annual fuel energy for gas pool heaters, E_F, is given by the following equation:

$$E_F = BOH \times Q_{IN} + (POH - BOH) \times Q_P$$

Then the burner operating hours (BOH) can be written as follows:

$$BOH = \frac{PHL}{Q_{IN} \times E_t}$$

Eq. 7B.6

Where:

BOH = average number of burner (active mode) operating hours, h/yr,
PHL = pool heater annual heating load, kBtu/year,

Q_{IN} = rated fuel energy input, kBtu/h, and
E_t = thermal efficiency, percent.

DOE determined the PHL by replacing E_F with the calculated annual energy consumption (Q_{RECS}):

$$PHHL = \left(\frac{Q_{IN}}{Q_{IN} - Q_P}\right)(Q_{RECS} - Q_P \times POH) \times E_t$$

Eq. 7B.7

Finally, because Q_P is much smaller than Q_{IN} for pool heaters, DOE approximated the PHL using the following formula:

$$PHL = (Q_{RECS} - Q_P \times POH) \times E_{t,existing}$$

Eq. 7B.8

Where:

Q_{RECS} = pool heater annual energy consumption from RECS 2015, kBtu/yr,
Q_{PR} = average energy consumption rate of continuously operating pilot light, if employed, kBtu/h,
POH = average number of pool operating hours per year, h/yr, and
$E_{t,existing}$ = thermal efficiency of the household's existing pool, percent.

Pool heater annual fuel consumption (Q_{RECS}) for each household with a pool heater comes from RECS 2015. For consumer pool heaters in single family homes, DOE was able to use the energy use estimates provided in RECS 2015 to estimate the pool heater load for each sampled pool or spa. For consumer pool heaters in single family homes (pool heater market type 1, 2, and 3), RECS 2015 provides estimates of the annual energy consumption from the household's energy bills using conditional demand analysis. The estimated annual electricity usage for EPHs used in spas and annual natural gas usage for GPHs used in swimming and hot tubs is disaggregated, but electricity use for EPHs used in swimming pools and annual propane usage for GPHs used in swimming and hot tubs is not disaggregated and instead is included in the "usage for other devices and purposes not elsewhere classified" category. Based on all the available information in RECS 2015, DOE then compared the average energy use between similar households that had an electric or gas-fired pool heater and those that did not to serve as a basis for estimating the energy use for all EPHs and GPHs in the RECS 2015 sample. For example, in most cases the fuel energy consumption in RECS 2015 includes other gas appliances such as gas clothes dryers and/or gas cooking equipment. For households having a pool heater and gas clothes dryers and/or gas cooking equipment, DOE subtracted the energy use of this equipment from the fuel energy consumption provided in RECS. DOE estimated that the energy gas clothes dryers and/or gas cooking equipment by developing a normal distribution based on households without pool heaters that had different combinations of clothes dryers and/or gas cooking equipment, with a minimum value equal to zero and a maximum value of twice the average.

7B.4 DETERMINING POOL HEATER ANNUAL LOAD FOR THE COMMERCIAL SECTOR

To estimate the annual energy consumption of pool heaters in commercial applications (including community and multi-family pools), DOE calculated the *PHL* based on assumptions about size of a typical pool, ambient conditions for different locations, length of swimming pool season, and whether the pool has a cover or not.[a] Given that energy usage varies significantly depending on ambient conditions, usage patterns, and pool operating hours, DOE developed a triangular distribution of *PHL* for both covered and uncovered pools based on modeling parameters from the DOE Energy Saver estimates for pool heater energy use.[7]

DOE's estimated average heating load for an average 30,000-gallon outdoor swimming pool in a representative city for each state without a pool cover are shown in Table 7B.4.1. DOE assumes that an outdoor pool is closed if monthly average temperature is below 35 deg F. On average a 30,000-gallon indoor swimming pool is assumed to average 13 MMBtu/month. DOE assumes that the assigned swimming pool heating load can vary 50 percent more or less than the average estimated value based on various factors such as wind, shading, fraction of the time with sunlight, swimming pool setpoint water temperature, etc. If a cover is used DOE estimated that the pool heating load can decrease between 30 to 70 percent.

DOE used 2022 Pkdata to determine average months of operation for consumer pool heaters in commercial applications (see Table 7B.4.2). DOE assumed that half of commercial consumers would operate around this average, while the rest would operate year-round.

[a] Neither RECS 2015 or CBECS 2012 provide any energy use data for pool heaters in community pools or spas or in other commercial applications.

Table 7B.4.1 Estimated Pool Heating Energy Use for 30,000 Gallon Swimming Pool

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Alabama	44.0	36.5	33.1	24.7	16.5	9.5	7.5	7.5	12.6	23.6	31.3	40.4	287.3
Alaska	0.0	0.0	0.0	51.1	44.6	34.6	31.2	32.3	40.4	53.4	0.0	0.0	287.7
Arizona	40.5	34.1	34.2	27.8	22.7	14.9	8.9	9.3	14.1	23.2	32.5	39.8	301.8
Arkansas	50.1	41.6	38.4	27.3	18.4	10.9	8.7	9.0	15.0	26.8	37.0	47.4	330.5
California	35.7	30.4	32.2	28.9	26.8	22.2	18.7	18.3	18.2	23.6	28.7	35.0	318.7
Colorado	0.0	0.0	50.7	42.9	36.4	27.4	22.3	23.8	30.8	41.6	49.0	0.0	324.9
Connecticut	0.0	0.0	50.7	41.2	31.5	20.2	15.5	15.8	22.2	34.3	43.1	53.4	328.0
Delaware	0.0	0.0	48.6	37.1	27.3	16.9	13.1	13.8	20.2	32.7	43.1	52.9	305.7
District of Columbia	52.9	46.5	45.8	34.6	25.1	15.6	11.3	12.7	17.7	30.0	41.2	50.7	383.9
Florida	20.9	18.4	17.5	14.5	10.1	7.3	6.1	6.1	6.1	9.8	14.1	19.3	150.2
Georgia	47.9	41.3	38.4	28.7	21.0	12.6	10.1	11.3	15.3	27.3	36.3	46.1	336.2
Hawaii	15.8	14.3	15.5	14.1	13.1	11.9	10.9	10.6	10.2	11.3	12.6	15.5	155.7
Idaho	0.0	47.7	48.6	42.4	35.9	27.9	23.2	25.0	31.5	41.2	48.5	0.0	371.7
Illinois	0.0	0.0	52.1	41.2	31.5	20.8	15.8	17.5	23.9	37.1	48.5	0.0	288.3
Indiana	0.0	0.0	49.3	37.8	26.8	16.9	13.5	15.8	21.8	34.9	45.9	0.0	262.7
Iowa	0.0	0.0	52.9	39.2	28.7	18.4	13.5	15.5	23.9	27.4	49.0	0.0	268.4
Kansas	0.0	48.3	46.6	33.4	24.0	15.2	11.5	12.9	19.7	32.4	44.6	0.0	288.6
Kentucky	0.0	47.0	45.3	33.4	24.0	15.0	11.6	13.1	19.4	32.2	42.5	52.1	335.5
Louisiana	36.2	30.1	27.3	18.7	13.8	7.5	6.3	6.3	9.3	18.3	27.0	33.9	234.7
Maine	0.0	0.0	0.0	46.4	37.1	24.9	19.3	21.5	28.0	41.1	49.0	0.0	267.3
Maryland	0.0	47.7	47.1	37.3	26.1	16.4	13.1	13.5	19.7	32.7	42.5	52.1	348.2
Massachusetts	0.0	0.0	50.7	42.6	33.1	21.3	16.5	17.5	23.9	35.8	44.6	0.0	285.7
Michigan	0.0	0.0	52.9	41.8	31.5	21.3	17.5	17.8	24.3	38.3	48.5	0.0	293.7
Minnesota	0.0	0.0	0.0	44.3	33.3	20.8	16.5	18.4	27.5	41.2	0.0	0.0	202.0
Mississippi	45.2	38.4	32.7	23.9	16.2	9.8	7.5	7.8	11.9	24.6	32.2	41.1	291.6
Missouri	0.0	0.0	47.1	35.1	26.1	15.0	11.3	13.1	20.2	34.3	45.9	0.0	248.1
Montana	0.0	0.0	0.0	46.4	40.5	31.4	26.8	28.8	36.5	46.6	0.0	0.0	256.9
Nebraska	0.0	0.0	51.4	38.6	28.2	16.9	13.1	15.0	23.3	36.9	49.0	0.0	272.5
Nevada	46.6	38.8	38.8	31.5	26.2	18.5	14.0	14.9	20.6	30.3	38.9	45.8	365.0
New Hampshire	0.0	0.0	0.0	45.6	35.2	23.9	18.9	20.9	28.5	41.7	49.8	0.0	264.5
New Jersey	0.0	0.0	48.6	39.2	28.2	18.4	14.2	14.6	21.3	33.1	42.5	52.9	312.9
New Mexico	53.4	45.2	45.1	37.6	32.5	23.9	18.9	19.9	25.5	37.4	45.0	52.9	437.4
New York	0.0	0.0	47.9	39.1	29.1	18.4	14.2	14.6	21.3	33.1	42.6	52.1	312.4
North Carolina	50.1	43.3	41.8	31.4	22.5	13.4	10.4	12.0	17.3	28.9	38.4	48.6	358.0
North Dakota	0.0	0.0	0.0	46.4	36.4	23.3	18.4	21.5	31.1	44.6	0.0	0.0	221.6
Ohio	0.0	0.0	52.1	41.2	31.5	20.2	17.0	17.8	24.3	36.5	45.9	0.0	286.6
Oklahoma	52.9	44.6	41.8	30.7	21.5	12.6	10.2	11.5	16.9	28.7	41.2	50.1	362.6
Oregon	50.2	42.1	42.6	37.0	32.2	26.4	23.0	23.0	25.9	33.9	41.6	48.0	425.7
Pennsylvania	0.0	0.0	48.6	37.9	27.3	17.4	13.1	13.5	20.2	32.7	42.5	52.9	305.9
Rhode Island	0.0	0.0	51.4	42.6	33.1	21.8	15.8	17.8	24.3	36.5	45.2	0.0	288.7
South Carolina	42.0	35.9	33.7	24.8	17.0	10.1	7.8	8.0	11.9	22.5	31.1	40.4	285.2
South Dakota	0.0	0.0	0.0	45.0	36.4	25.3	20.3	22.2	32.1	43.0	51.7	0.0	276.1
Tennessee	43.9	36.4	33.7	24.8	17.5	10.9	7.8	9.0	13.1	24.6	33.8	41.7	297.1
Texas	38.4	32.2	27.3	19.7	13.8	8.7	7.3	7.3	9.3	87.0	27.0	35.6	313.4
Utah	0.0	0.0	49.3	41.6	35.2	26.3	20.6	21.9	29.6	40.5	48.5	0.0	313.5
Vermont	0.0	0.0	0.0	46.4	35.2	23.9	19.9	20.9	28.0	41.7	50.4	0.0	266.4
Virginia	51.4	45.2	44.0	32.9	24.0	14.5	10.4	12.0	17.3	30.0	39.9	49.3	370.9
Washington	50.2	42.1	45.2	39.8	34.9	28.4	25.7	24.6	28.0	36.8	42.3	48.0	445.9
West Virginia	0.0	47.0	46.6	35.9	26.1	16.9	13.8	14.2	20.2	32.7	43.1	52.1	348.7
Wisconsin	0.0	0.0	0.0	44.6	34.9	23.3	17.8	18.3	25.4	38.4	49.8	0.0	252.4
Wyoming	0.0	0.0	0.0	46.9	41.2	30.7	25.5	27.6	35.2	45.1	51.7	0.0	304.0
United States	44.0	36.5	33.1	24.7	16.5	9.5	7.5	7.5	12.6	23.6	31.3	40.4	287.3

Table 7B.4.2 Average Pool Operating Hours (POH) by State

State	Average Months	Maximum Number of Months
Alabama	4.8	12
Alaska	3	7
Arizona	6.2	12
Arkansas	4.5	12
California	5.9	12
Colorado	4.3	9
Connecticut	4.7	10
Delaware	4.5	10
District of Columbia	4.2	12
Florida	7.3	12
Georgia	5.6	12
Hawaii	8	12
Idaho	4	10
Illinois	4.7	9
Indiana	4.5	9
Iowa	4.1	9
Kansas	4.4	10
Kentucky	4.5	11
Louisiana	5.3	12
Maine	4.1	8
Maryland	5.4	11
Massachusetts	4.5	9
Michigan	4.2	9
Minnesota	4	7
Mississippi	4.6	12
Missouri	4.7	9
Montana	4	7
Nebraska	4.2	9
Nevada	4.6	12
New Hampshire	4.1	8
New Jersey	4.8	10
New Mexico	4.7	12
New York	4.3	10
North Carolina	5.3	12
North Dakota	4	7
Ohio	4.7	9
Oklahoma	5.6	12
Oregon	4.5	12
Pennsylvania	4.5	10
Rhode Island	4.7	9
South Carolina	5.3	12
South Dakota	4	8
Tennessee	5.2	12
Texas	6.3	12
Utah	4.3	9
Vermont	4	8
Virginia	5.3	12
Washington	4.5	12
West Virginia	4.1	11
Wisconsin	4.1	8
Wyoming	4	8

7B.5 DETERMINING HEAT PUMP POOL HEATER PERFORMANCE CURVES

Heat pump pool heaters (HPPHs) have unique characteristics compared to electric resistance pool heaters and GPHs. DOE took into account variations of output capacity (Q_{out}), input capacity (Q_{IN}), and E_t or *COP* observed in the field based on the ambient field conditions at different geographical location. DOE used the efficiency ratings at different ambient conditions for heat pump pool heaters (based primarily on DOE's Compliance Certification Database (CCD),[8] the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance (AHRI Directory),[9] the California Energy Commission (CEC) Modernized Appliance Efficiency Database System (MAEDbS; CEC Database),[10] and manufacturer literature) to derive average efficiency performance curves at each efficiency level. DOE then accounted for outdoor air temperature and pool season length in determine the average field adjuted Q_{out} and *COP* value for each heat pump efficiency level for each climate region (Hot Humid, Warm, or Cold climate). These curves are then used to estimate the monthly energy use based on the ambient temperature for the installation location of the heat pump pool heater (see Figure 7B.5.1).

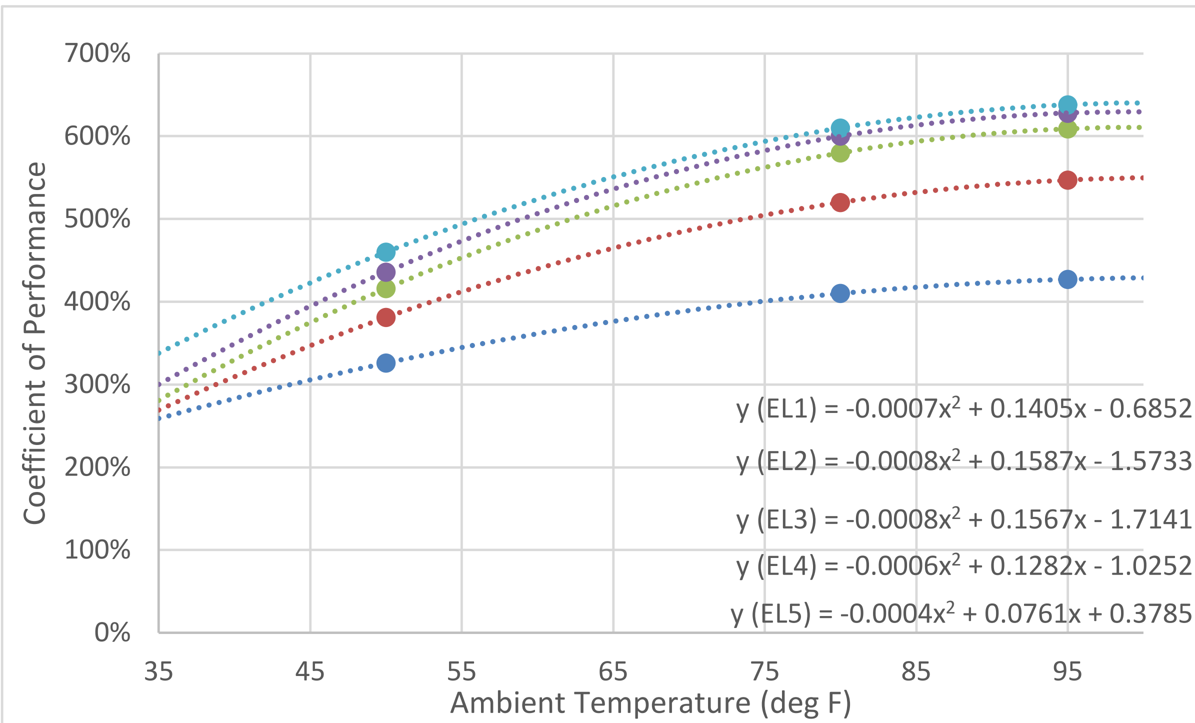

Figure 7B.5.1 Derived Heat Pump Pool Heater Performance Curves (COP vs. Ambient Temperature) by Efficiency Level

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APPENDIX 7C. MAPPING OF WEATHER STATION DATA TO RECS AND CBECS BUILDINGS

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7C.1 INTRODUCTION

The Energy Information Administration's (EIA) 2015 Residential Energy Consumption Survey (RECS 2015)[1] and EIA's 2012 Commercial Building Energy Consumption Survey (CBECS 2012)[2] provide annual data on heating and cooling degree-days but not on other weather parameters needed for the analysis such as monthly heating degree days (HDD) and monthly cooling degree days (CDD), and average outdoor temperature. Monthly HDD are used to disaggregate the annual energy use provided by RECS and CBECS by month. Monthly energy use and monthly energy prices are used in conjunction to determine the monthly operating cost (see appendix 7B). Finally, this mapping allowed DOE to assign each individual sampled household or building to a state, thus allowing DOE to use state level inputs such as labor rates, markups, and energy prices.

7C.2 MAPPING METHODOLOGY

To derive the additional weather data that is needed for the analysis (*e.g.*, ODT, average outdoor temperature, monthly HDD, monthly CDD), for each building in the sample, DOE developed an approach to assign a physical location to each RECS household and CBECS building. [a] The methodology consists of the following steps:

1. DOE assembled monthly weather data from 360 weather stations from the National Oceanic and Atmospheric Administration (NOAA) that provide the heating and cooling degree-days at base temperature 65°F for year 2015 (for the RECS sample) and year 2012 (for the CBECS sample), for these weather stations.[3] The 2015 and 2012 heating and cooling degree days match the period used to determine the degree-days in RECS 2015 and in CBECS 2012, respectively.
2. RECS 2015 and CBECS 2012 report both HDD and CDD to base temperature 65°F for each building record. DOE assigned each building to one of the 360 weather stations by calculating which weather station (within the appropriate region) was the closest using the best linear least squares fit of the RECS 2015 and CBECS 2012 data to the weather data for each region in the RECS 2015 and CBECS 2012 data. To differential between the heating and cooling degree days is normalized using the maximum heating and cooling degree days by region from the weather station data.
3. To make sure that the final weighting of RECS households by state matches the U.S. Census housing data,[b] DOE added a state weighting correction factor. DOE does not have any comparable state level data for commercial buildings, so no correction factor was added to CBECS 2012 weather station matching.

Eq. 7C.1 calculates the U.S. weather station closest (or with minimum "distance") to the RECS/CBECS building:

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[a] For confidentiality, heating and cooling degree day values were altered slightly by EIA to mask the exact geographic location of the housing unit or building.
[b] U.S. Census Bureau, Population Division. Annual Estimates of Housing Units for the United States, Regions, and States: April 1, 2010 to July 1, 2019 (NST-EST2019-ANNHU). May 2020

$$\text{"Distance"} = \left(\sqrt{\frac{(HDD_2 - HDD_1)^2}{HDD_{MAX}^2} + \frac{(CDD_2 - CDD_1)^2}{CDD_{MAX}^2}}\right) \times StateCorrectionFactor$$

Eq. 7C.1

Where:

HDD_1 = heating degree days from U.S. weather data,
HDD_2 = heating degree days from RECS/CBECS data,
HDD_{MAX} = maximum heating degree days from U.S. weather data,
CDD_1 = cooling degree days from U.S. weather data,
CDD_2 = cooling degree days from RECS/CBECS data,
CDD_{MAX} = maximum cooling degree days from U.S. weather data,
StateCorrectionFactor = adjustment factor used to be able to match the U.S. Census housing data for RECS households.

7C.3 MAPPING RESULTS

Table 7C.3.1 shows the imputation results for all RECS and CBECS locations. Note that some U.S. weather station data match with several of the RECS/CBECS weather data. The number of RECS/CBECS buildings that were matched to the specified weather station is indicated in the column "Count". Table 7C.3.1 shows the data matches (360 weather stations) including the heating and cooling degree days as well as annual average outdoor temperature for each of the weather stations.[c]

Table 7C.3.1 Weather Station Mapping Statistics, Heating and Cooling ODT, and Average Outdoor Temperature

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
BHM	BIRMINGHAM	Alabama	1974	2247	2284	2295
HSV	HUNTSVILLE	Alabama	2345	2098	2503	2303
MOB	MOBILE	Alabama	1136	2709	1409	2872
MGM	MONTGOMERY	Alabama	1495	2601	1694	2874
MSL	MUSCLE SHOALS	Alabama	2306	2226	2732	2046
TCL	TUSCALOOSA	Alabama	1833	2412	2113	2432
ANC	ANCHORAGE	Alaska	10880	0	9037	36
BRW	BARROW	Alaska	18900	0	18456	0
BET	BETHEL	Alaska	14234	0	11086	12
BTT	BETTLES	Alaska	16413	12	14022	52
BIG	BIG DELTA	Alaska	14103	18	12045	41
CDB	COLD BAY	Alaska	10803	0	8705	0
CDV	CORDOVA	Alaska	10235	0	8513	0
FAI	FAIRBANKS	Alaska	14867	35	12613	69
GKN	GULKANA	Alaska	14544	2	12445	6
HOM	HOMER	Alaska	10760	0	8014	3
JNU	JUNEAU	Alaska	8901	1	7330	8
ENA	KENAI	Alaska	12063	0	9745	5

[c] The names of weather stations MQT, SSI, and SSM changed to SAW, BQK, and ANJ, respectively.

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
KTN	KETCHIKAN	Alaska	7386	4	5949	29
AKN	KING SALMON	Alaska	12551	0	9064	2
ADQ	KODIAK	Alaska	9334	0	7350	2
OTZ	KOTZEBUE	Alaska	16649	0	13901	22
MCG	MCGRATH	Alaska	14961	4	12110	42
OME	NOME	Alaska	15028	0	12819	6
ORT	NORTHWAY	Alaska	15735	11	13934	9
SNP	ST PAUL ISLAND	Alaska	12111	0	9747	0
SIT	SITKA	Alaska	7745	0	6346	1
TKA	TALKEETNA	Alaska	11469	3	9699	32
UNK	UNALAKLEET	Alaska	15229	0	12651	4
VWS	VALDEZ	Alaska	7554	19	5850	173
YAK	YAKUTAT	Alaska	9563	0	7915	0
DUG	DOUGLAS	Arizona	2067	2074	2418	1891
FLG	FLAGSTAFF	Arizona	6167	164	6301	114
PHX	PHOENIX	Arizona	681	5078	679	5078
TUS	TUCSON	Arizona	1181	3607	1033	3530
INW	WINSLOW	Arizona	4033	1464	4013	1332
NYL	YUMA	Arizona	560	4943	463	5192
ELD	EL DORADO	Arkansas	2119	2311	2514	2431
FYV	FAYETTEVILLE	Arkansas	3293	1798	3871	1327
FSM	FORT SMITH	Arkansas	2354	2871	2864	2260
HRO	HARRISON	Arkansas	3071	1981	3663	1521
LIT	LITTLE ROCK	Arkansas	2247	2638	2680	2497
TXK	TEXARKANA	Arkansas	1893	2820	2406	2561
BFL	BAKERSFIELD	California	1731	2590	1633	2827
BLH	BLYTHE	California	861	4639	833	4767
EKA	EUREKA	California	5333	10	4300	17
FAT	FRESNO	California	1875	2657	1862	2538
IPL	IMPERIAL	California	826	4451	697	4644
LAX	LOS ANGELES	California	1208	742	922	1234
MHS	MT SHASTA	California	5365	405	4430	558
PRB	PASO ROBLES	California	2494	1170	2150	1331
RBL	RED BLUFF	California	2473	2048	1867	2335
RDD	REDDING	California	2742	1991	1918	2555
SAC	SACRAMENTO	California	2404	1338	1926	1622
SAN	SAN DIEGO	California	1078	908	549	1574
SFO	SAN FRANCISCO	California	2681	82	1898	334
SCK	STOCKTON	California	2417	1401	1993	1713
AKO	AKRON	Colorado	5397	1273	5679	1014
ALS	ALAMOSA	Colorado	8012	132	7387	76
COS	COLORADO SPRINGS	Colorado	5149	877	5497	625
DEN	DENVER	Colorado	5152	1248	5456	874
EGE	EAGLE	Colorado	6728	344	6616	279
GJT	GRAND JUNCTION	Colorado	4972	1533	5200	1053
LHX	LA JUNTA	Colorado	4402	1740	4334	1446
PUB	PUEBLO	Colorado	4887	1351	4812	1301
TAD	TRINIDAD	Colorado	4682	1182	4872	960
BDR	BRIDGEPORT	Connecticut	4406	1079	5263	1112
BDL	HARTFORD	Connecticut	5024	962	5921	946
ILG	WILMINGTON	Delaware	4085	1378	4630	1378
DCA	WASHINGTON	District of Columbia	3163	1969	3656	1991
DAB	DAYTONA BEACH	Florida	569	3171	456	3745
FLL	FT LAUDERDALE	Florida	83	4597	74	5185
FMY	FORT MYERS	Florida	161	4367	148	4592
GNV	GAINESVILLE	Florida	813	2989	858	3268
JAX	JACKSONVILLE	Florida	1027	2736	977	3082

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
EYW	KEY WEST	Florida	35	4798	22	5561
MLB	MELBOURNE	Florida	373	3496	296	4179
MIA	MIAMI	Florida	73	4665	50	5310
MCO	ORLANDO	Florida	402	3572	333	4266
PNS	PENSACOLA	Florida	893	3051	1116	3072
TLH	TALLAHASSEE	Florida	1115	2956	1001	3556
TPA	TAMPA	Florida	287	3962	308	4470
VRB	VERO BEACH	Florida	307	3524	239	4409
PBI	WEST PALM BEACH	Florida	150	4225	88	4933
ABY	ALBANY	Georgia	1334	2792	1399	2940
AHN	ATHENS	Georgia	2198	1946	2373	2098
ATL	ATLANTA	Georgia	1946	2224	2209	2136
AGS	AUGUSTA	Georgia	2008	2142	2063	2339
BQK	BRUNSWICK	Georgia	1036	3013	1186	2713
CSG	COLUMBUS	Georgia	1463	2643	1770	2518
MCN	MACON	Georgia	1842	2283	2000	2364
SAV	SAVANNAH	Georgia	1358	2661	1381	2833
AYS	WAYCROSS	Georgia	1098	2769	969	3624
ITO	HILO-HAWAII	Hawaii	0	3209	0	4198
HNL	HONOLULU-OAHU	Hawaii	0	4540	0	5095
OGG	KAHULUI-MAUI	Hawaii	1	3968	0	4597
LIH	LIHUE-KAUAI	Hawaii	0	4164	0	4520
BOI	BOISE	Idaho	4690	1276	4677	1285
BYI	BURLEY	Idaho	5801	573	5691	512
IDA	IDAHO FALLS	Idaho	6587	462	6656	350
LWS	LEWISTON	Idaho	4684	1051	4204	1241
PIH	POCATELLO	Idaho	6241	567	5959	513
ORD	CHICAGO	Illinois	5057	1326	6089	805
MLI	MOLINE	Illinois	5259	1210	5825	1018
PIA	PEORIA	Illinois	4777	1377	5094	1420
UIN	QUINCY	Illinois	4474	1581	5068	1232
RFD	ROCKFORD	Illinois	5459	1229	6230	828
SPI	SPRINGFIELD	Illinois	4229	1541	4952	1377
EVV	EVANSVILLE	Indiana	3648	1842	4063	1579
FWA	FORT WAYNE	Indiana	5127	1094	5956	799
IND	INDIANAPOLIS	Indiana	4422	1523	5174	1152
SBN	SOUTH BEND	Indiana	5284	1102	6083	776
LAF	WEST LAFAYETTE	Indiana	4837	1195	5758	810
BRL	BURLINGTON	Iowa	4852	1337	5398	1110
CID	CEDAR RAPIDS	Iowa	5893	1066	6288	736
DSM	DES MOINES	Iowa	4779	1615	5344	1213
DBQ	DUBUQUE	Iowa	6082	933	6663	638
MCW	MASON CITY	Iowa	6320	901	6994	653
OTM	OTTUMWA	Iowa	5154	1245	5636	936
SUX	SIOUX CITY	Iowa	5715	1249	5930	902
SPW	SPENCER	Iowa	6296	1044	6712	728
ALO	WATERLOO	Iowa	5951	1085	6587	747
CNU	CHANUTE	Kansas	3497	2014	4030	1621
CNK	CONCORDIA	Kansas	4364	1643	4686	1376
DDC	DODGE CITY	Kansas	4178	1769	4429	1514
GCK	GARDEN CITY	Kansas	4383	1655	4673	1458
GLD	GOODLAND	Kansas	4984	1361	5134	1152
RSL	RUSSELL	Kansas	4331	1861	4528	1646
SLN	SALINA	Kansas	3964	2063	4195	1875
TOP	TOPEKA	Kansas	3774	1979	4461	1536
ICT	WICHITA	Kansas	3496	2309	3868	1907
BWG	BOWLING GREEN	Kentucky	3076	1942	3645	1681

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
JKL	JACKSON	Kentucky	3596	1311	3868	1260
LEX	LEXINGTON	Kentucky	4005	1345	4349	1272
SDF	LOUISVILLE	Kentucky	3392	1940	3770	1771
PAH	PADUCAH	Kentucky	3584	1681	4082	1485
BTR	BATON ROUGE	Louisiana	1093	3007	1363	3206
LFT	LAFAYETTE	Louisiana	974	3138	1200	3324
LCH	LAKE CHARLES	Louisiana	873	3225	1263	3170
MLU	MONROE	Louisiana	1560	2839	2066	2749
MSY	NEW ORLEANS	Louisiana	764	3415	1004	3600
SHV	SHREVEPORT	Louisiana	1478	2953	1919	3023
AUG	AUGUSTA	Maine	6713	476	7538	452
BGR	BANGOR	Maine	7052	384	8114	395
CAR	CARIBOU	Maine	8413	268	9224	245
HUL	HOULTON	Maine	8380	271	9192	228
PWM	PORTLAND	Maine	6195	486	6912	485
BWI	BALTIMORE	Maryland	3802	1564	4549	1406
SBY	SALISBURY	Maryland	3296	1850	4041	1338
BOS	BOSTON	Massachusetts	4769	903	5683	916
CHH	CHATHAM	Massachusetts	4940	684	5746	575
ORH	WORCESTER	Massachusetts	5632	675	6501	647
APN	ALPENA	Michigan	6946	466	7798	373
DTW	DETROIT	Michigan	5152	1145	5957	876
FNT	FLINT	Michigan	5661	860	6259	754
GRR	GRAND RAPIDS	Michigan	5421	1026	6402	629
CMX	HANCOCK	Michigan	7857	260	8695	263
HTL	HOUGHTON LAKE	Michigan	6773	546	7879	316
JXN	JACKSON	Michigan	5726	865	6524	523
LAN	LANSING	Michigan	5743	928	6529	597
SAW	MARQUETTE	Michigan	7752	340	8801	254
MKG	MUSKEGON	Michigan	5403	907	6308	563
MBS	SAGINAW	Michigan	5741	856	6430	714
ANJ	SAULT ST MARIE	Michigan	7407	398	8554	357
TVC	TRAVERSE CITY	Michigan	6181	795	7113	560
AXN	ALEXANDRIA	Minnesota	7478	709	7756	522
DLH	DULUTH	Minnesota	7959	412	8394	345
HIB	HIBBING	Minnesota	8904	197	9161	211
INL	INT'L FALLS	Minnesota	9053	223	9533	213
MSP	MINNEAPOLIS	Minnesota	6209	1133	6730	810
RST	ROCHESTER	Minnesota	6194	890	7279	509
STC	SAINT CLOUD	Minnesota	7185	744	7598	495
GWO	GREENWOOD	Mississippi	2106	2270	2253	2503
JAN	JACKSON	Mississippi	1671	2523	1885	2809
MCB	MCCOMB	Mississippi	1391	2501	1548	2794
MEI	MERIDIAN	Mississippi	1886	2176	2044	2336
TUP	TUPELO	Mississippi	2272	2212	2654	2178
COU	COLUMBIA	Missouri	3841	1897	4347	1390
JLN	JOPLIN	Missouri	3275	2117	3847	1710
MCI	KANSAS CITY	Missouri	4025	1839	4563	1373
STL	SAINT LOUIS	Missouri	3495	2221	3975	1874
SGF	SPRINGFIELD	Missouri	3646	1769	4049	1559
BIL	BILLINGS	Montana	5925	971	5838	765
BTM	BUTTE	Montana	8451	124	8369	106
CTB	CUT BANK	Montana	8035	213	7692	248
GGW	GLASGOW	Montana	7644	688	7367	643
GTF	GREAT FALLS	Montana	6745	504	6864	418
HVR	HAVRE	Montana	7532	517	7384	430
HLN	HELENA	Montana	6873	564	6509	570

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
FCA	KALISPELL	Montana	4843	1648	7220	265
LWT	LEWISTOWN	Montana	7602	330	6942	407
MLS	MILES CITY	Montana	6439	1151	6381	850
MSO	MISSOULA	Montana	6812	418	6791	403
GRI	GRAND ISLAND	Nebraska	5030	1509	5498	1051
LNK	LINCOLN	Nebraska	5184	1500	5334	1245
OFK	NORFOLK	Nebraska	5570	1386	5634	988
LBF	NORTH PLATTE	Nebraska	5861	1247	5834	841
OMA	OMAHA	Nebraska	4898	1653	5311	1218
BFF	SCOTTSBLUFF	Nebraska	5456	1216	5948	794
VTN	VALENTINE	Nebraska	5953	1305	6292	842
EKO	ELKO	Nevada	6112	699	5828	629
ELY	ELY	Nevada	6412	318	6395	344
LAS	LAS VEGAS	Nevada	1638	4045	1480	4084
LOL	LOVELOCK	Nevada	5004	1226	5020	964
RNO	RENO	Nevada	4301	1277	4081	1201
TPH	TONOPAH	Nevada	4828	1029	4354	1202
WMC	WINNEMUCCA	Nevada	5753	759	5350	751
CON	CONCORD	New Hampshire	6285	584	7075	623
LEB	LEBANON	New Hampshire	6476	553	7481	537
MWN	MT WASHINGTON	New Hampshire	12551	0	13407	0
ACY	ATLANTIC CITY	New Jersey	4025	1239	4686	1283
EWR	NEWARK	New Jersey	3990	1438	4669	1541
ABQ	ALBUQUERQUE	New Mexico	3539	1782	3748	1537
CNM	CARLSBAD	New Mexico	2292	2541	2616	2420
CAO	CLAYTON	New Mexico	3916	1455	4354	1113
GUP	GALLUP	New Mexico	5789	586	5593	471
ROW	ROSWELL	New Mexico	2650	2364	3140	2099
CVN	TUCUMCARI	New Mexico	3298	1659	3811	1384
ALB	ALBANY	New York	5618	797	6439	894
BGM	BINGHAMTON	New York	6152	544	6995	437
BUF	BUFFALO	New York	5505	863	6540	646
GFL	GLENS FALLS	New York	6408	524	7306	633
MSS	MASSENA	New York	6963	514	8034	440
LGA	NEW YORK	New York	3792	1503	4496	1544
ROC	ROCHESTER	New York	5499	786	6426	681
SYR	SYRACUSE	New York	5402	938	6793	709
UCA	UTICA	New York	3609	2424	4931	2123
ART	WATERTOWN	New York	6296	613	7504	373
AVL	ASHEVILLE	North Carolina	3424	1008	3553	1143
HAT	CAPE HATTERAS	North Carolina	598	4079	1202	4328
CLT	CHARLOTTE	North Carolina	2672	1772	2811	2017
GSO	GREENSBORO	North Carolina	3023	1616	3209	1770
HKY	HICKORY	North Carolina	2977	1530	3198	1679
EWN	NEW BERN	North Carolina	2261	2013	2308	2207
RDU	RALEIGH DURHAM	North Carolina	2692	1860	2976	1899
ILM	WILMINGTON	North Carolina	2130	1987	2195	2178
BIS	BISMARCK	North Dakota	7609	601	7652	624
P11	DEVIL'S LAKE	North Dakota	8444	741	8626	478
DIK	DICKINSON	North Dakota	7495	609	7557	489
FAR	FARGO	North Dakota	7500	797	7679	679
GFK	GRAND FORKS	North Dakota	8266	572	8458	478
JMS	JAMESTOWN	North Dakota	7845	583	8113	514
MOT	MINOT	North Dakota	7922	594	8026	508
ISN	WILLISTON	North Dakota	8115	534	7819	618
CAK	AKRON CANTON	Ohio	5102	1035	5659	947
CLE	CLEVELAND	Ohio	5030	1086	5826	823

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
CMH	COLUMBUS	Ohio	4470	1424	5219	1020
CVG	CINCINNATI	Ohio	4270	1426	4660	1151
DAY	DAYTON	Ohio	4777	1248	5179	1068
FDY	FINDLAY	Ohio	5091	1131	5652	956
MFD	MANSFIELD	Ohio	5276	949	5894	772
TOL	TOLEDO	Ohio	5304	985	6258	713
YNG	YOUNGSTOWN	Ohio	5382	748	6110	674
LHQ	ZANESVILLE	Ohio	4932	1036	5259	841
GAG	GAGE	Oklahoma	3391	2339	3793	1914
HBR	HOBART	Oklahoma	2872	2714	3235	2288
MLC	MCALESTER	Oklahoma	2459	2563	2826	2297
OKC	OKLAHOMA CITY	Oklahoma	2714	2508	3066	2045
PNC	PONCA CITY	Oklahoma	3106	2622	2845	3137
TUL	TULSA	Oklahoma	2711	2717	3190	2160
AST	ASTORIA	Oregon	5147	25	3903	51
BKE	BAKER	Oregon	7072	197	6536	267
BNO	BURNS	Oregon	7009	311	6593	341
EUG	EUGENE	Oregon	4495	237	3822	534
MFR	MEDFORD	Oregon	4128	963	3443	1300
OTH	NORTH BEND	Oregon	4630	1	3603	15
PDT	PENDLETON	Oregon	5085	623	4619	925
PDX	PORTLAND	Oregon	4141	443	3420	794
RDM	REDMOND	Oregon	6372	233	5784	373
SLE	SALEM	Oregon	4391	316	3553	686
ABE	ALLENTOWN	Pennsylvania	4776	1041	5471	1046
AOO	ALTOONA	Pennsylvania	5053	823	5688	685
BFD	BRADFORD	Pennsylvania	6333	353	7454	277
DUJ	DU BOIS	Pennsylvania	5895	584	6282	647
ERI	ERIE	Pennsylvania	5204	889	6104	767
CXY	HARRISBURG	Pennsylvania	4355	1260	5059	1196
PHL	PHILADELPHIA	Pennsylvania	3773	1592	4277	1711
PIT	PITTSBURGH	Pennsylvania	4889	1015	5405	965
AVP	SCRANTON	Pennsylvania	5162	834	5753	921
IPT	WILLIAMSPORT	Pennsylvania	4961	934	5726	936
PVD	PROVIDENCE	Rhode Island	4831	830	5643	946
CHS	CHARLESTON	South Carolina	1530	2447	1552	2685
CAE	COLUMBIA	South Carolina	1877	2483	1993	2642
FLO	FLORENCE	South Carolina	1911	2305	2107	2532
GSP	GREENVILLE	South Carolina	2422	1811	2630	1939
ABR	ABERDEEN	South Dakota	7332	765	7368	679
HON	HURON	South Dakota	6572	1087	6950	797
PIR	PIERRE	South Dakota	6430	1114	6560	840
RAP	RAPID CITY	South Dakota	6154	952	6466	590
FSD	SIOUX FALLS	South Dakota	6363	1178	6709	716
ATY	WATERTOWN	South Dakota	7348	794	7447	593
TRI	BRISTOL	Tennessee	3597	1181	3769	1299
CHA	CHATTANOOGA	Tennessee	2470	2016	2735	1997
CSV	CROSSVILLE	Tennessee	3478	1183	3636	1190
MKL	JACKSON	Tennessee	2829	1922	3304	1874
TYS	KNOXVILLE	Tennessee	2909	1705	3276	1702
MEM	MEMPHIS	Tennessee	2192	2617	2647	2478
BNA	NASHVILLE	Tennessee	2856	1979	3116	1886
ABI	ABILENE	Texas	1898	3050	2417	2736
ALI	ALICE	Texas	552	4528	932	4020
AMA	AMARILLO	Texas	3231	2012	3689	1488
AUS	AUSTIN	Texas	1386	3165	1774	2874
BRO	BROWNSVILLE	Texas	251	4822	587	4227

Station Location			CBECS 2012	CBECS 2012	RECS 2015	RECS 2015
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**
CLL	COLLEGE STATION	Texas	1068	3629	1558	3253
CRP	CORPUS CHRISTI	Texas	470	4518	966	3754
DHT	DALHART	Texas	3803	1656	3927	1545
DFW	DALLAS FT WORTH	Texas	1665	3352	2093	3011
DRT	DEL RIO	Texas	1033	4116	1353	3573
ELP	EL PASO	Texas	1986	2884	2073	2851
GLS	GALVESTON	Texas	564	3950	1062	3584
IAH	HOUSTON	Texas	866	3575	1286	3344
LRD	LAREDO	Texas	554	5205	952	4421
LBB	LUBBOCK	Texas	2773	2322	3118	1918
LFK	LUFKIN	Texas	1281	3231	1578	3099
MFE	MCALLEN	Texas	307	5233	624	4954
MAF	MIDLAND ODESSA	Texas	2119	2919	2511	2643
PSX	PALACIOS	Texas	675	3821	1094	3587
CXO	PORT ARTHUR	Texas	1285	2960	1634	2868
SJT	SAN ANGELO	Texas	1725	3239	2130	2931
SAT	SAN ANTONIO	Texas	1054	3601	1348	3505
VCT	VICTORIA	Texas	792	3747	1148	3336
ACT	WACO	Texas	1668	3241	2107	3057
SPS	WICHITA FALLS	Texas	2312	2970	2675	2471
CDC	CEDAR CITY	Utah	5556	720	5559	712
SLC	SALT LAKE CITY	Utah	4594	1623	4491	1455
BTV	BURLINGTON	Vermont	6176	728	7173	761
MPV	MONTPELIER	Vermont	7321	289	8374	282
LYH	LYNCHBURG	Virginia	3728	1237	4146	1185
ORF	NORFOLK	Virginia	2576	1845	3053	1968
RIC	RICHMOND	Virginia	3075	1737	3547	1813
ROA	ROANOKE	Virginia	3363	1412	3808	1403
BLI	BELLINGHAM	Washington	5231	49	4389	201
HQM	HOQUIAM	Washington	5189	33	4097	36
OLM	OLYMPIA	Washington	5434	87	4499	296
UIL	QUILLAYUTE	Washington	5674	28	4576	58
SEA	SEATTLE TACOMA	Washington	4687	181	3768	478
GEG	SPOKANE	Washington	6209	550	5501	836
ALW	WALLA WALLA	Washington	4555	894	4015	1386
EAT	WENATCHEE	Washington	5544	918	4556	1451
YKM	YAKIMA	Washington	5449	717	4570	1106
BKW	BECKLEY	West Virginia	4528	751	4782	748
CRW	CHARLESTON	West Virginia	3905	1330	4193	1258
EKN	ELKINS	West Virginia	5505	564	5671	457
HTS	HUNTINGTON	West Virginia	3901	1318	4389	1126
MRB	MARTINSBURG	West Virginia	4300	1222	4724	1102
MGW	MORGANTOWN	West Virginia	4396	1132	4758	1202
PKB	PARKERSBURG	West Virginia	4354	1214	4770	1034
EAU	EAU CLAIRE	Wisconsin	6755	834	7297	532
GRB	GREEN BAY	Wisconsin	6388	786	7002	518
LSE	LACROSSE	Wisconsin	6028	1091	6347	887
MSN	MADISON	Wisconsin	5959	1070	6659	668
MKE	MILWAUKEE	Wisconsin	5693	1044	6464	623
AUW	WAUSAU	Wisconsin	6875	730	7506	435
CPR	CASPER	Wyoming	6539	714	6777	440
CYS	CHEYENNE	Wyoming	6272	579	6370	412
COD	CODY	Wyoming	6496	669	6513	479
LND	LANDER	Wyoming	6478	796	6981	528
RKS	ROCK SPRINGS	Wyoming	6911	544	7091	269
SHR	SHERIDAN	Wyoming	6728	671	6680	528
WRL	WORLAND	Wyoming	6569	926	7154	701

7C.3.1 Developing Monthly Heating and Cooling Degree Day Fractions

Table 7C.3.2 and Table 7C.3.3 show the 10-year average monthly HDD and CDD data based on NOAA data for each weather station.[3] This data was then used to determine the monthly fractions of HDD and CDD as shown in Table 7C.3.4 and Table 7C.3.5. Monthly HDD are used to disaggregate the annual energy use provided by RECS and CBECS by month. The monthly energy use is then combined with monthly energy prices to find the monthly operating cost (see appendix 8D for more details).

Table 7C.3.2 Weather Station Monthly Heating Degree Day Data (10-Year Average, 2012-2021)

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	606	428	261	98	23	0	0	0	3	78	348	461
HSV	HUNTSVILLE	AL	678	507	329	131	31	0	0	0	5	105	408	520
MOB	MOBILE	AL	426	264	149	44	6	0	0	0	0	31	213	315
MGM	MONTGOMERY	AL	499	316	186	55	9	0	0	0	0	44	281	370
MSL	MUSCLE SHOALS	AL	664	506	315	126	26	0	0	0	4	105	401	519
TCL	TUSCALOOSA	AL	572	404	235	85	16	0	0	0	1	70	337	434
ANC	ANCHORAGE	AK	1423	1212	1193	791	481	225	122	185	426	792	1204	1339
BRW	BARROW	AK	2265	2108	2227	1757	1234	835	673	755	903	1221	1640	2149
BET	BETHEL	AK	1726	1420	1520	1009	627	301	244	306	549	903	1353	1576
BTT	BETTLES	AK	2303	1933	1856	1185	568	189	149	345	687	1222	1899	2139
BIG	BIG DELTA	AK	1970	1628	1537	938	482	193	128	275	582	1100	1703	1879
CDB	COLD BAY	AK	1091	909	1028	832	693	486	361	332	473	680	854	994
CDV	CORDOVA	AK	1136	1004	1038	798	582	378	291	313	462	735	999	1093
FAI	FAIRBANKS	AK	2225	1825	1638	941	417	126	75	217	550	1075	1781	2073
GKN	GULKANA	AK	2018	1704	1524	954	554	282	176	318	585	1112	1750	1984
HOM	HOMER	AK	1184	999	1054	765	555	348	250	270	432	707	992	1113
JNU	JUNEAU	AK	1034	978	968	701	449	284	205	236	412	690	923	1070
ENA	KENAI	AK	1494	1243	1251	838	577	355	251	280	487	818	1222	1398
KTN	KETCHIKAN	AK	854	822	811	615	406	272	161	163	302	558	720	897
AKN	KING SALMON	AK	1431	1130	1264	832	579	338	229	268	483	800	1168	1336
ADQ	KODIAK	AK	1035	898	959	755	576	370	228	236	402	656	851	982
OTZ	KOTZEBUE	AK	1953	1766	1901	1353	891	443	249	339	634	1051	1578	1872
MCG	MCGRATH	AK	2151	1703	1606	975	492	170	135	257	571	1024	1648	1953
OME	NOME	AK	1769	1560	1684	1194	796	442	373	415	648	961	1355	1655
ORT	NORTHWAY	AK	2361	1984	1721	1009	514	234	147	302	631	1227	1983	2322
SNP	ST PAUL ISLAND	AK	1156	1040	1157	964	816	597	477	423	521	712	882	1036
SIT	SITKA	AK	827	797	818	642	481	328	219	200	313	547	712	827
TKA	TALKEETNA	AK	1547	1290	1282	843	494	216	125	227	491	877	1290	1463
UNK	UNALAKLEET	AK	1796	1513	1611	1086	695	386	261	330	596	965	1512	1674
VWS	VALDEZ	AK	1022	836	829	516	266	85	46	70	251	481	829	920
YAK	YAKUTAT	AK	1056	966	1005	777	568	373	270	280	432	693	926	1050
DUG	DOUGLAS	AZ	525	350	213	94	23	0	0	0	1	54	254	488
FLG	FLAGSTAFF	AZ	1001	819	697	499	365	72	13	34	152	429	684	966
PHX	PHOENIX	AZ	235	135	41	2	0	0	0	0	0	3	54	247
TUS	TUCSON	AZ	324	220	93	20	1	0	0	0	0	12	97	322
INW	WINSLOW	AZ	894	653	484	261	101	2	0	0	20	234	562	882
NYL	YUMA	AZ	171	105	39	3	0	0	0	0	0	2	36	203
ELD	EL DORADO	AR	611	482	273	113	19	0	0	0	2	100	356	496
FYV	FAYETTEVILLE	AR	851	706	467	246	84	2	0	0	17	230	523	733
FSM	FORT SMITH	AR	721	575	324	133	29	0	0	0	1	118	394	610
HRO	HARRISON	AR	795	676	418	205	65	1	0	0	10	173	441	647
LIT	LITTLE ROCK	AR	693	539	303	122	25	0	0	0	2	115	405	571
TXK	TEXARKANA	AR	594	469	253	105	17	0	0	0	1	87	324	482
BFL	BAKERSFIELD	CA	417	285	172	61	11	0	0	0	1	32	214	447

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BLH	BLYTHE	CA	270	149	53	4	1	0	0	0	0	5	81	280
EKA	EUREKA	CA	528	493	509	429	387	286	238	230	246	343	437	552
FAT	FRESNO	CA	448	307	192	71	15	1	0	0	1	29	233	486
IPL	IMPERIAL	CA	248	147	54	6	1	0	0	0	0	5	65	266
LAX	LOS ANGELES	CA	199	188	161	95	57	6	1	0	0	12	75	207
MHS	MT SHASTA	CA	802	679	636	404	194	68	5	5	94	325	568	822
PRB	PASO ROBLES	CA	455	378	308	161	71	11	1	0	8	86	286	504
RBL	RED BLUFF	CA	481	352	289	124	21	1	0	0	4	56	294	515
RDD	REDDING	CA	496	371	311	140	25	3	0	0	6	74	326	539
SAC	SACRAMENTO	CA	491	342	244	117	32	4	0	0	3	56	303	522
SAN	SAN DIEGO	CA	182	153	113	52	25	5	0	0	0	6	54	189
SFO	SAN FRANCISCO	CA	376	293	266	194	148	63	47	30	39	69	223	390
SCK	STOCKTON	CA	487	347	260	116	25	3	0	0	2	54	287	504
AKO	AKRON	CO	1059	1006	712	521	280	19	3	7	82	444	714	1073
ALS	ALAMOSA	CO	1520	1083	863	630	406	91	19	63	223	617	980	1426
COS	COLORADO SPRINGS	CO	989	917	700	508	269	25	4	7	74	426	705	992
DEN	DENVER	CO	987	951	696	505	266	22	1	5	70	418	696	1017
EGE	EAGLE	CO	1312	1015	824	607	374	57	5	22	160	574	884	1283
GJT	GRAND JUNCTION	CO	1171	834	585	375	147	9	0	1	45	380	720	1134
LHX	LA JUNTA	CO	954	826	550	333	128	3	0	0	30	305	625	949
PUB	PUEBLO	CO	980	858	610	385	161	6	0	0	39	356	671	983
TAD	TRINIDAD	CO	948	819	613	427	207	13	1	2	53	350	643	936
BDR	BRIDGEPORT	CT	1009	890	768	449	168	18	0	0	32	222	585	818
BDL	HARTFORD	CT	1132	985	826	475	172	29	2	2	75	321	694	955
ILG	WILMINGTON	DE	940	792	641	317	96	7	0	0	21	185	528	722
DCA	WASHINGTON	DC	833	681	515	224	58	1	0	0	5	130	472	652
DAB	DAYTONA BEACH	FL	190	95	72	6	1	0	0	0	0	5	46	87
FLL	FT LAUDERDALE	FL	37	16	8	0	0	0	0	0	0	0	4	11
FMY	FORT MYERS	FL	81	34	17	0	0	0	0	0	0	1	10	31
GNV	GAINESVILLE	FL	282	158	105	15	2	0	0	0	0	14	99	152
JAX	JACKSONVILLE	FL	331	201	138	30	3	0	0	0	0	16	141	211
EYW	KEY WEST	FL	12	5	2	0	0	0	0	0	0	0	0	4
MLB	MELBOURNE	FL	138	69	48	3	0	0	0	0	0	3	28	65
MIA	MIAMI	FL	29	14	5	0	0	0	0	0	0	0	3	12
MCO	ORLANDO	FL	161	70	44	3	0	0	0	0	0	4	34	74
PNS	PENSACOLA	FL	355	200	114	22	2	0	0	0	0	12	155	237
TLH	TALLAHASSEE	FL	370	216	136	31	3	0	0	0	0	21	174	248
TPA	TAMPA	FL	142	64	38	1	0	0	0	0	0	1	27	60
VRB	VERO BEACH	FL	101	52	43	3	0	0	0	0	0	4	20	41
PBI	WEST PALM BEACH	FL	56	26	17	0	0	0	0	0	0	1	7	25
ABY	ALBANY	GA	345	213	118	24	5	0	0	0	0	16	133	194
AHN	ATHENS	GA	615	447	291	114	25	0	0	0	3	100	362	479
ATL	ATLANTA	GA	601	427	269	101	22	0	0	0	3	73	337	450
AGS	AUGUSTA	GA	541	379	249	92	13	0	0	0	0	61	329	412
BQK	BRUNSWICK	GA	374	242	162	51	3	0	0	0	0	22	183	255
CSG	COLUMBUS	GA	502	334	200	61	10	0	0	0	1	40	260	369
MCN	MACON	GA	535	370	239	90	15	0	0	0	1	60	316	401
SAV	SAVANNAH	GA	408	267	174	48	3	0	0	0	0	25	213	282
AYS	WAYCROSS	GA	351	204	129	34	3	0	0	0	0	21	177	247
ITO	HILO-HAWAII	HI	0	0	5	5	0	0	0	0	0	0	0	0
HNL	HONOLULU-OAHU	HI	0	0	0	0	0	0	0	0	0	0	0	0
OGG	KAHULUI-MAUI	HI	0	0	1	0	0	0	0	0	0	0	1	0
LIH	LIHUE-KAUAI	HI	1	0	0	0	0	0	0	0	0	0	2	0
BOI	BOISE	ID	1020	761	573	380	162	40	1	1	69	352	703	1023
BYI	BURLEY	ID	1087	858	695	511	277	78	6	14	146	485	766	1092
IDA	IDAHO FALLS	ID	1342	1091	837	581	336	107	12	28	193	598	906	1320
LWS	LEWISTON	ID	877	739	599	361	139	40	1	1	60	360	667	914
PIH	POCATELLO	ID	1190	942	753	542	308	87	6	16	161	541	840	1196
ORD	CHICAGO	IL	1223	1083	790	483	192	19	3	1	52	350	742	1015
MLI	MOLINE	IL	1262	1113	766	429	144	7	2	1	59	362	756	1045
PIA	PEORIA	IL	1185	1040	709	379	124	5	2	0	39	316	711	978
UIN	QUINCY	IL	1114	967	640	339	103	4	2	1	32	270	630	894
RFD	ROCKFORD	IL	1299	1170	829	483	178	12	2	2	71	391	792	1081
SPI	SPRINGFIELD	IL	1110	970	657	336	107	3	2	1	37	302	673	921

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EVV	EVANSVILLE	IN	940	787	546	257	76	2	0	0	18	223	595	762
FWA	FORT WAYNE	IN	1177	1039	801	463	157	14	3	6	75	349	736	976
IND	INDIANAPOLIS	IN	1108	932	683	359	123	6	1	1	37	293	685	912
SBN	SOUTH BEND	IN	1215	1079	839	514	202	24	5	8	75	368	749	1008
LAF	WEST LAFAYETTE	IN	1172	1013	735	409	144	12	5	4	61	336	728	964
BRL	BURLINGTON	IA	1180	1037	696	366	112	3	3	1	42	292	670	960
CID	CEDAR RAPIDS	IA	1355	1212	849	492	184	12	6	7	90	439	835	1154
DSM	DES MOINES	IA	1239	1111	720	393	132	3	0	1	46	357	734	1073
DBQ	DUBUQUE	IA	1394	1252	896	539	210	19	7	9	104	446	861	1181
MCW	MASON CITY	IA	1463	1329	950	581	232	17	9	18	114	516	921	1279
OTM	OTTUMWA	IA	1246	1112	752	430	155	8	4	4	66	386	750	1059
SUX	SIOUX CITY	IA	1301	1186	784	478	184	11	3	7	75	453	824	1192
SPW	SPENCER	IA	1389	1275	868	523	182	16	7	14	80	437	827	1226
ALO	WATERLOO	IA	1401	1262	886	517	192	12	4	8	94	454	862	1188
CNU	CHANUTE	KS	917	804	483	250	81	2	0	0	15	224	535	795
CNK	CONCORDIA	KS	1058	943	601	349	118	3	1	0	39	298	627	966
DDC	DODGE CITY	KS	954	862	564	343	118	4	1	0	29	286	602	923
GCK	GARDEN CITY	KS	1001	894	598	375	134	5	1	0	36	321	636	975
GLD	GOODLAND	KS	1027	954	670	456	204	15	2	3	64	404	693	1025
RSL	RUSSELL	KS	1014	909	589	356	123	4	1	0	37	303	628	960
SLN	SALINA	KS	986	863	540	305	93	2	0	0	23	261	582	915
TOP	TOPEKA	KS	1010	888	544	299	90	1	0	0	26	275	598	894
ICT	WICHITA	KS	920	807	488	265	74	2	0	0	13	217	545	844
BWG	BOWLING GREEN	KY	843	676	469	215	59	1	0	0	16	184	530	661
JKL	JACKSON	KY	870	693	495	224	73	4	0	0	21	190	502	654
LEX	LEXINGTON	KY	948	784	578	290	95	7	0	0	30	234	603	753
SDF	LOUISVILLE	KY	888	729	497	215	59	1	0	0	13	183	532	691
PAH	PADUCAH	KY	890	749	508	239	68	2	0	0	18	213	557	713
BTR	BATON ROUGE	LA	379	226	115	33	5	0	0	0	0	22	178	260
LFT	LAFAYETTE	LA	378	236	113	33	4	0	0	0	0	19	175	276
LCH	LAKE CHARLES	LA	378	233	111	31	4	0	0	0	0	19	168	279
MLU	MONROE	LA	534	401	207	79	9	0	0	0	0	62	302	425
MSY	NEW ORLEANS	LA	328	186	90	17	2	0	0	0	0	10	134	221
SHV	SHREVEPORT	LA	505	381	188	72	8	0	0	0	0	55	265	410
AUG	AUGUSTA	ME	1325	1169	1030	635	296	88	12	12	137	442	826	1159
BGR	BANGOR	ME	1339	1204	1050	634	267	87	8	11	140	421	813	1161
CAR	CARIBOU	ME	1578	1418	1255	794	389	146	36	45	235	587	980	1394
HUL	HOULTON	ME	1536	1404	1232	787	421	178	47	59	254	593	958	1347
PWM	PORTLAND	ME	1223	1086	960	617	311	87	8	9	127	414	777	1071
BWI	BALTIMORE	MD	936	777	622	307	97	6	0	0	24	204	564	742
SBY	SALISBURY	MD	819	677	554	272	84	7	0	0	9	145	440	612
BOS	BOSTON	MA	1033	908	810	482	213	42	3	0	50	267	613	861
CHH	CHATHAM	MA	963	858	794	521	255	63	2	2	54	236	544	774
ORH	WORCESTER	MA	1175	1022	905	544	234	62	5	7	98	341	701	976
APN	ALPENA	MI	1366	1272	1088	751	367	115	25	35	189	518	860	1154
DTW	DETROIT	MI	1180	1056	829	496	173	18	2	3	70	347	732	977
FNT	FLINT	MI	1228	1132	891	551	210	36	4	11	113	397	772	1031
GRR	GRAND RAPIDS	MI	1211	1110	889	550	209	29	4	8	89	403	762	1029
CMX	HANCOCK	MI	1459	1385	1199	852	452	168	57	81	238	613	965	1286
HTL	HOUGHTON LAKE	MI	1380	1286	1069	704	315	91	30	46	198	526	880	1181
JXN	JACKSON	MI	1232	1115	885	546	217	38	7	14	110	414	784	1028
LAN	LANSING	MI	1244	1131	902	560	221	35	6	12	108	415	783	1040
SAW	MARQUETTE	MI	1500	1411	1193	864	454	164	71	94	255	644	1001	1337
MKG	MUSKEGON	MI	1168	1090	900	576	243	36	8	10	86	389	728	992
MBS	SAGINAW	MI	1242	1150	922	578	225	35	4	9	103	403	773	1052
ANJ	SAULT ST MARIE	MI	1445	1343	1162	795	386	132	34	38	192	543	904	1248
TVC	TRAVERSE CITY	MI	1258	1181	991	678	314	74	16	16	120	440	786	1074
AXN	ALEXANDRIA	MN	1595	1460	1071	682	271	31	7	16	142	582	1010	1458
DLH	DULUTH	MN	1617	1462	1135	787	396	117	26	45	209	625	1050	1466
HIB	HIBBING	MN	1742	1593	1217	845	449	157	59	114	309	728	1153	1589
INL	INT'L FALLS	MN	1779	1628	1235	840	425	127	48	105	286	711	1144	1628
MSP	MINNEAPOLIS	MN	1453	1310	922	570	199	12	3	3	85	482	892	1299
RST	ROCHESTER	MN	1502	1370	987	615	246	24	8	19	121	522	931	1323
STC	SAINT CLOUD	MN	1567	1426	1043	672	283	35	8	23	154	586	997	1427

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GWO	GREENWOOD	MS	574	430	245	92	17	0	0	0	1	77	303	426
JAN	JACKSON	MS	532	376	208	81	12	0	0	0	0	61	303	407
MCB	MCCOMB	MS	469	309	166	61	9	0	0	0	0	41	242	350
MEI	MERIDIAN	MS	545	382	221	85	13	0	0	0	1	68	318	416
TUP	TUPELO	MS	654	506	306	123	23	0	0	0	2	101	398	518
COU	COLUMBIA	MO	1013	879	554	287	91	2	0	0	21	270	596	851
JLN	JOPLIN	MO	883	758	464	243	84	3	0	0	14	228	508	754
MCI	KANSAS CITY	MO	1050	920	575	324	102	4	0	1	31	290	619	912
STL	SAINT LOUIS	MO	961	825	524	249	70	1	0	0	12	216	562	790
SGF	SPRINGFIELD	MO	923	788	506	266	92	4	0	0	17	248	553	784
BIL	BILLINGS	MT	1118	1096	797	552	292	46	2	21	143	522	812	1151
BTM	BUTTE	MT	1309	1217	968	717	480	221	43	84	288	658	988	1330
CTB	CUT BANK	MT	1224	1245	996	690	416	174	38	64	258	641	924	1270
GGW	GLASGOW	MT	1438	1367	991	623	291	53	5	25	182	621	1036	1447
GTF	GREAT FALLS	MT	1158	1192	913	652	399	134	23	48	232	617	897	1225
HVR	HAVRE	MT	1353	1311	995	637	345	96	12	37	219	659	1011	1362
HLN	HELENA	MT	1240	1131	864	578	333	92	7	24	180	578	920	1244
FCA	KALISPELL	MT	1188	1069	822	527	266	121	36	60	267	658	930	1212
LWT	LEWISTOWN	MT	1218	1233	957	709	454	177	31	62	264	654	932	1256
MLS	MILES CITY	MT	1324	1227	869	575	288	41	1	17	141	567	921	1308
MSO	MISSOULA	MT	1201	1042	836	587	329	132	19	30	213	624	933	1208
GRI	GRAND ISLAND	NE	1158	1066	699	432	167	7	2	2	56	385	722	1085
LNK	LINCOLN	NE	1187	1075	684	399	138	4	1	2	54	369	722	1079
OFK	NORFOLK	NE	1246	1147	766	468	195	14	4	7	73	443	787	1162
LBF	NORTH PLATTE	NE	1162	1087	736	506	239	18	4	7	80	470	793	1142
OMA	OMAHA	NE	1200	1084	685	384	131	3	1	1	44	352	720	1080
BFF	SCOTTSBLUFF	NE	1106	1024	732	520	264	18	2	8	86	485	776	1126
VTN	VALENTINE	NE	1202	1128	788	547	251	19	3	9	89	489	805	1203
EKO	ELKO	NV	1127	905	736	535	308	69	2	6	137	509	811	1166
ELY	ELY	NV	1159	983	820	616	416	101	6	16	179	562	844	1186
LAS	LAS VEGAS	NV	442	283	130	26	5	0	0	0	0	20	186	478
LOL	LOVELOCK	NV	970	753	612	372	161	28	0	1	83	369	666	989
RNO	RENO	NV	823	668	558	336	154	26	0	1	50	301	592	877
TPH	TONOPAH	NV	912	762	625	380	166	19	0	0	52	337	644	962
WMC	WINNEMUCCA	NV	1010	787	697	495	270	69	3	5	132	493	750	1080
CON	CONCORD	NH	1267	1124	972	599	256	69	6	17	142	437	820	1113
LEB	LEBANON	NH	1300	1148	983	580	205	60	5	14	121	386	783	1091
MWN	MT WASHINGTON	NH	1796	1654	1623	1256	855	590	430	479	623	957	1346	1599
ACY	ATLANTIC CITY	NJ	944	790	684	379	134	14	0	0	31	216	567	743
EWR	NEWARK	NJ	974	828	678	355	112	9	0	0	20	196	553	770
ABQ	ALBUQUERQUE	NM	840	624	421	218	67	1	0	0	15	188	522	826
CNM	CARLSBAD	NM	646	459	254	96	20	0	0	0	8	111	358	588
CAO	CLAYTON	NM	873	771	543	368	157	8	0	2	40	308	565	856
GUP	GALLUP	NM	1060	838	703	498	284	22	3	8	92	446	752	1057
ROW	ROSWELL	NM	710	504	293	118	24	0	0	0	8	126	405	671
CVN	TUCUMCARI	NM	808	640	441	257	83	2	0	0	24	230	506	764
ALB	ALBANY	NY	1224	1065	898	534	196	41	3	7	109	376	766	1022
BGM	BINGHAMTON	NY	1284	1119	987	621	261	79	11	28	152	437	826	1074
BUF	BUFFALO	NY	1179	1081	915	589	222	46	3	6	86	361	726	974
GFL	GLENS FALLS	NY	1316	1163	979	577	216	68	4	16	134	399	787	1079
MSS	MASSENA	NY	1459	1304	1113	668	279	83	14	24	176	481	890	1216
LGA	NEW YORK	NY	933	799	675	355	111	8	0	0	11	160	498	727
ROC	ROCHESTER	NY	1181	1065	906	577	218	46	4	9	99	362	727	978
SYR	SYRACUSE	NY	1228	1098	942	571	213	48	2	6	99	359	746	1008
UCA	UTICA	NY	999	876	682	294	42	0	0	0	11	156	547	815
ART	WATERTOWN	NY	1332	1213	1030	664	298	94	13	25	163	431	804	1102
AVL	ASHEVILLE	NC	816	627	485	247	79	3	0	1	23	207	537	656
HAT	CAPE HATTERAS	NC	289	230	158	23	0	0	0	0	0	2	80	164
CLT	CHARLOTTE	NC	699	516	374	151	38	1	0	0	7	116	433	538
GSO	GREENSBORO	NC	781	600	446	189	56	2	0	0	14	146	486	614
HKY	HICKORY	NC	737	559	408	183	47	2	0	0	8	129	428	560
EWN	NEW BERN	NC	611	462	357	140	26	0	0	0	2	69	341	445
RDU	RALEIGH DURHAM	NC	715	552	423	174	47	1	0	0	7	125	445	550
ILM	WILMINGTON	NC	564	429	325	119	20	0	0	0	1	61	319	405

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BIS	BISMARCK	ND	1495	1373	1012	675	300	39	7	19	159	619	1020	1455
P11	DEVIL'S LAKE	ND	1554	1455	1095	652	219	31	10	16	107	510	976	1447
DIK	DICKINSON	ND	1457	1321	1023	722	365	83	14	35	214	648	1041	1423
FAR	FARGO	ND	1614	1489	1102	689	263	29	8	19	150	597	1032	1502
GFK	GRAND FORKS	ND	1658	1540	1163	724	295	47	10	26	160	595	1057	1548
JMS	JAMESTOWN	ND	1584	1474	1115	738	320	45	8	31	189	651	1057	1510
MOT	MINOT	ND	1514	1437	1084	720	302	49	10	25	184	642	1055	1482
ISN	WILLISTON	ND	1440	1370	984	619	265	50	8	24	173	579	985	1394
CAK	AKRON CANTON	OH	1125	988	787	444	158	21	2	3	65	313	699	915
CLE	CLEVELAND	OH	1104	987	793	464	177	22	2	3	62	299	674	894
CMH	COLUMBUS	OH	1064	919	688	364	124	9	0	1	42	284	663	864
CVG	CINCINNATI	OH	1014	853	631	319	108	7	1	0	34	263	641	817
DAY	DAYTON	OH	1101	937	712	379	124	11	1	3	52	295	678	891
FDY	FINDLAY	OH	1143	1007	773	437	143	13	2	3	58	310	696	931
MFD	MANSFIELD	OH	1139	993	789	444	158	25	3	6	64	298	681	910
TOL	TOLEDO	OH	1181	1057	825	488	175	20	3	5	75	346	723	970
YNG	YOUNGSTOWN	OH	1157	1014	826	490	194	39	6	11	95	355	727	941
LHQ	ZANESVILLE	OH	1080	931	711	397	139	16	2	5	70	321	697	875
GAG	GAGE	OK	809	731	408	229	68	1	0	0	10	185	452	742
HBR	HOBART	OK	754	652	366	188	41	0	0	0	7	148	391	690
MLC	MCALESTER	OK	702	588	328	155	35	0	0	0	3	142	382	581
OKC	OKLAHOMA CITY	OK	766	655	366	189	43	1	0	0	7	161	431	699
PNC	PONCA CITY	OK	739	639	347	172	38	1	0	0	5	142	375	632
TUL	TULSA	OK	776	660	368	174	43	1	0	0	4	161	429	676
AST	ASTORIA	OR	636	592	580	449	314	195	110	86	151	341	501	664
BKE	BAKER	OR	1155	912	776	584	350	162	24	40	235	577	870	1183
BNO	BURNS	OR	1200	935	802	602	376	161	20	39	245	615	912	1239
EUG	EUGENE	OR	712	607	551	382	230	101	10	7	83	328	558	742
MFR	MEDFORD	OR	740	589	488	292	118	40	0	0	42	253	546	780
OTH	NORTH BEND	OR	493	471	476	363	243	163	100	93	126	224	367	511
PDT	PENDLETON	OR	910	770	620	399	186	62	2	4	93	388	700	937
PDX	PORTLAND	OR	706	601	512	326	147	58	3	3	55	273	508	715
RDM	REDMOND	OR	917	815	715	521	306	145	25	26	178	447	733	970
SLE	SALEM	OR	697	601	541	364	189	76	7	5	71	308	534	720
ABE	ALLENTOWN	PA	1069	919	756	405	143	16	0	2	59	282	674	883
AOO	ALTOONA	PA	1118	1022	916	516	240	96	53	53	154	423	815	1019
BFD	BRADFORD	PA	1280	1134	981	626	287	106	35	56	183	457	853	1054
DUJ	DU BOIS	PA	1215	1061	885	528	219	57	8	20	125	390	786	1004
ERI	ERIE	PA	1115	1018	862	548	219	39	2	4	66	295	664	891
CXY	HARRISBURG	PA	1019	860	682	350	116	8	0	1	36	232	611	819
PHL	PHILADELPHIA	PA	936	786	639	311	90	4	0	0	15	178	533	733
PIT	PITTSBURGH	PA	1107	942	750	410	148	21	1	4	64	315	694	890
AVP	SCRANTON	PA	1137	972	823	467	167	31	1	4	83	312	700	919
IPT	WILLIAMSPORT	PA	1129	967	789	445	155	19	0	2	66	307	709	920
PVD	PROVIDENCE	RI	1045	918	801	476	194	33	1	0	53	282	633	871
CHS	CHARLESTON	SC	444	314	214	64	6	0	0	0	0	33	249	317
CAE	COLUMBIA	SC	556	400	264	85	14	0	0	0	1	64	339	429
FLO	FLORENCE	SC	560	416	298	97	15	0	0	0	2	63	330	420
GSP	GREENVILLE	SC	682	509	352	141	37	1	0	0	7	115	411	531
ABR	ABERDEEN	SD	1523	1403	1023	652	269	33	9	20	146	591	1000	1443
HON	HURON	SD	1449	1316	932	595	240	23	6	16	105	534	920	1355
PIR	PIERRE	SD	1296	1208	850	556	244	24	4	9	79	449	819	1236
RAP	RAPID CITY	SD	1198	1169	850	636	345	50	4	19	137	557	862	1220
FSD	SIOUX FALLS	SD	1407	1281	883	558	229	20	5	10	88	497	889	1294
ATY	WATERTOWN	SD	1551	1429	1046	685	296	37	10	23	145	596	990	1434
TRI	BRISTOL	TN	830	643	475	231	68	2	0	0	14	185	512	641
CHA	CHATTANOOGA	TN	701	519	336	135	28	0	0	0	4	108	424	548
CSV	CROSSVILLE	TN	827	646	475	232	75	6	0	0	20	186	481	621
MKL	JACKSON	TN	764	620	414	191	51	0	0	0	10	162	475	623
TYS	KNOXVILLE	TN	781	596	413	185	52	0	0	0	10	153	496	617
MEM	MEMPHIS	TN	677	546	318	130	26	0	0	0	2	105	389	538
BNA	NASHVILLE	TN	757	596	394	171	45	1	0	0	8	143	463	594
ABI	ABILENE	TX	581	461	233	103	21	0	0	0	5	93	291	506
ALI	ALICE	TX	241	155	64	9	0	0	0	0	0	12	91	186

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
AMA	AMARILLO	TX	797	689	426	248	84	1	0	0	19	217	488	757
AUS	AUSTIN	TX	447	316	151	48	4	0	0	0	0	40	199	356
BRO	BROWNSVILLE	TX	160	97	32	4	0	0	0	0	0	4	47	101
CLL	COLLEGE STATION	TX	374	263	119	37	4	0	0	0	0	26	154	286
CRP	CORPUS CHRISTI	TX	245	154	58	8	0	0	0	0	0	11	88	179
DHT	DALHART	TX	814	704	455	283	94	1	0	0	16	215	478	757
DFW	DALLAS FT WORTH	TX	531	415	195	78	10	0	0	0	0	63	252	451
DRT	DEL RIO	TX	374	210	78	14	1	0	0	0	0	27	139	301
ELP	EL PASO	TX	566	345	163	43	7	0	0	0	2	46	258	519
GLS	GALVESTON	TX	277	171	67	12	1	0	3	0	0	7	86	189
IAH	HOUSTON	TX	349	229	104	29	2	0	0	0	0	20	150	269
LRD	LAREDO	TX	248	141	49	3	0	0	0	0	0	15	82	185
LBB	LUBBOCK	TX	717	577	330	157	43	0	0	0	14	160	410	670
LFK	LUFKIN	TX	458	318	157	58	5	0	0	0	0	46	226	375
MFE	MCALLEN	TX	161	98	30	3	0	0	0	0	0	8	54	115
MAF	MIDLAND ODESSA	TX	596	440	226	82	16	0	0	0	7	92	306	524
PSX	PALACIOS	TX	304	193	84	18	2	0	0	0	0	16	115	223
CXO	PORT ARTHUR	TX	441	297	156	55	6	0	0	0	0	42	214	352
SJT	SAN ANGELO	TX	539	394	197	71	14	0	0	0	4	80	267	454
SAT	SAN ANTONIO	TX	364	248	106	28	2	0	0	0	0	31	157	296
VCT	VICTORIA	TX	312	213	95	20	1	0	0	0	0	22	129	241
ACT	WACO	TX	522	394	210	80	9	0	0	0	0	62	252	442
SPS	WICHITA FALLS	TX	659	552	291	135	22	0	0	0	4	112	346	597
CDC	CEDAR CITY	UT	1050	858	688	480	268	28	0	2	89	435	727	1080
SLC	SALT LAKE CITY	UT	1034	772	548	370	147	18	0	1	50	323	641	1007
BTV	BURLINGTON	VT	1326	1168	1013	602	217	49	3	7	115	397	803	1104
MPV	MONTPELIER	VT	1447	1272	1141	725	333	136	29	51	211	524	932	1234
LYH	LYNCHBURG	VA	889	708	540	256	85	5	0	1	30	210	566	713
ORF	NORFOLK	VA	700	561	443	190	43	1	0	0	1	85	381	526
RIC	RICHMOND	VA	805	643	490	211	60	2	0	0	8	145	479	634
ROA	ROANOKE	VA	851	670	505	238	73	3	0	0	24	188	534	672
BLI	BELLINGHAM	WA	752	674	605	431	252	137	42	37	156	399	570	787
HQM	HOQUIAM	WA	655	606	580	443	317	200	112	85	146	347	521	684
OLM	OLYMPIA	WA	765	682	635	457	270	147	44	36	154	421	626	785
UIL	QUILLAYUTE	WA	688	637	636	495	359	246	145	115	202	401	563	728
SEA	SEATTLE TACOMA	WA	680	613	546	378	196	92	14	11	89	333	526	707
GEG	SPOKANE	WA	1079	935	754	495	230	100	9	11	140	503	817	1090
ALW	WALLA WALLA	WA	861	708	530	305	98	27	1	0	48	278	603	853
EAT	WENATCHEE	WA	1076	874	663	364	125	41	1	1	77	415	760	1081
YKM	YAKIMA	WA	978	797	633	370	143	51	2	5	105	419	741	1012
BKW	BECKLEY	WV	1007	822	671	362	144	24	4	6	65	306	659	811
CRW	CHARLESTON	WV	927	754	568	277	97	5	0	0	31	240	587	733
EKN	ELKINS	WV	1095	898	763	450	190	41	7	12	91	354	730	875
HTS	HUNTINGTON	WV	929	755	562	275	96	5	0	0	33	240	588	741
MRB	MARTINSBURG	WV	994	820	662	342	124	10	0	1	51	266	628	819
MGW	MORGANTOWN	WV	1006	840	661	346	130	15	1	1	48	265	619	792
PKB	PARKERSBURG	WV	977	804	612	323	93	11	1	1	40	254	610	758
EAU	EAU CLAIRE	WI	1512	1373	997	641	255	32	8	19	136	542	942	1339
GRB	GREEN BAY	WI	1396	1283	982	639	264	40	7	18	132	486	860	1207
LSE	LACROSSE	WI	1390	1262	881	519	180	12	2	3	69	424	818	1196
MSN	MADISON	WI	1369	1240	912	565	225	25	5	10	109	453	848	1166
MKE	MILWAUKEE	WI	1251	1126	870	587	271	53	7	5	74	378	760	1051
AUW	WAUSAU	WI	1505	1373	1029	674	272	47	11	26	163	551	952	1327
CPR	CASPER	WY	1205	1148	873	675	403	76	5	24	172	602	880	1234
CYS	CHEYENNE	WY	1070	1048	827	656	408	66	9	21	139	554	807	1101
COD	CODY	WY	1147	1114	821	640	397	99	9	42	202	588	870	1181
LND	LANDER	WY	1335	1147	845	634	375	67	3	18	145	591	914	1312
RKS	ROCK SPRINGS	WY	1302	1119	898	683	416	96	7	26	196	632	943	1325
SHR	SHERIDAN	WY	1207	1180	855	643	377	81	6	26	174	599	893	1237
WRL	WORLAND	WY	1434	1254	833	583	303	45	2	17	162	604	984	1425

Table 7C.3.3 Weather Station Monthly Cooling Degree Day Data (10-Year Average, 2012-2021)

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	2	10	36	74	244	419	518	489	366	137	13	10
HSV	HUNTSVILLE	AL	1	6	18	60	231	418	505	462	328	108	11	4
MOB	MOBILE	AL	12	29	77	113	290	461	529	526	424	208	36	28
MGM	MONTGOMERY	AL	6	21	62	104	288	474	564	554	432	181	25	17
MSL	MUSCLE SHOALS	AL	1	7	22	61	229	434	529	478	328	111	12	5
TCL	TUSCALOOSA	AL	4	13	39	74	259	449	534	516	392	145	18	13
ANC	ANCHORAGE	AK	0	0	0	0	0	4	14	5	0	0	0	0
BRW	BARROW	AK	0	0	0	0	0	0	0	0	0	0	0	0
BET	BETHEL	AK	0	0	0	0	0	4	10	1	0	0	0	0
BTT	BETTLES	AK	0	0	0	0	1	16	19	3	0	0	0	0
BIG	BIG DELTA	AK	0	0	0	0	1	18	24	6	0	1	0	0
CDB	COLD BAY	AK	0	0	0	0	0	0	0	0	0	0	0	0
CDV	CORDOVA	AK	0	0	0	0	0	1	0	0	0	0	0	0
FAI	FAIRBANKS	AK	0	0	0	0	2	36	41	10	0	0	0	0
GKN	GULKANA	AK	0	0	0	0	0	7	10	1	0	0	0	0
HOM	HOMER	AK	0	0	0	0	0	0	0	0	0	0	0	0
JNU	JUNEAU	AK	0	0	0	0	0	3	5	1	0	0	0	0
ENA	KENAI	AK	0	0	0	0	0	1	1	1	0	0	0	0
KTN	KETCHIKAN	AK	0	0	0	0	0	5	13	6	0	0	0	0
AKN	KING SALMON	AK	0	0	0	0	0	0	4	0	0	0	0	0
ADQ	KODIAK	AK	0	0	0	0	0	1	6	7	0	0	0	0
OTZ	KOTZEBUE	AK	0	0	0	0	0	5	10	2	0	0	0	0
MCG	MCGRATH	AK	0	0	0	0	1	17	21	4	0	0	0	0
OME	NOME	AK	0	0	0	0	0	2	2	0	0	0	0	0
ORT	NORTHWAY	AK	0	0	0	0	0	8	9	2	0	0	0	0
SNP	ST PAUL ISLAND	AK	0	0	0	0	0	0	0	0	0	0	0	0
SIT	SITKA	AK	0	0	0	0	0	0	2	0	0	0	0	0
TKA	TALKEETNA	AK	0	0	0	0	0	10	16	2	0	0	0	0
UNK	UNALAKLEET	AK	0	0	0	0	1	2	4	2	0	0	0	0
VWS	VALDEZ	AK	0	0	0	0	2	25	53	28	1	0	0	0
YAK	YAKUTAT	AK	0	0	0	0	0	0	0	1	0	0	0	0
DUG	DOUGLAS	AZ	3	12	38	125	263	566	565	513	374	156	61	10
FLG	FLAGSTAFF	AZ	0	0	0	10	46	135	191	148	71	16	1	0
PHX	PHOENIX	AZ	3	28	136	317	539	866	965	927	736	413	121	5
TUS	TUCSON	AZ	1	8	61	182	378	701	733	706	548	288	67	3
INW	WINSLOW	AZ	0	0	0	13	55	340	470	408	185	13	1	0
NYL	YUMA	AZ	9	46	148	303	480	774	945	952	749	436	134	12
ELD	EL DORADO	AR	3	7	29	63	230	433	528	520	363	114	19	12
FYV	FAYETTEVILLE	AR	0	1	7	23	113	303	404	356	216	50	7	3
FSM	FORT SMITH	AR	0	2	22	56	214	462	574	527	373	104	8	2
HRO	HARRISON	AR	0	2	18	47	157	361	505	451	301	100	20	7
LIT	LITTLE ROCK	AR	0	5	42	69	223	437	548	515	366	102	8	5
TXK	TEXARKANA	AR	2	6	34	73	242	458	552	536	390	142	21	12
BFL	BAKERSFIELD	CA	1	1	17	102	242	499	686	645	451	150	7	0
BLH	BLYTHE	CA	2	18	115	290	478	800	965	988	734	378	72	16
EKA	EUREKA	CA	0	0	0	0	0	0	0	1	3	2	0	0
FAT	FRESNO	CA	0	0	14	85	226	475	650	608	420	135	4	0
IPL	IMPERIAL	CA	2	30	112	266	439	734	915	928	701	365	82	4
LAX	LOS ANGELES	CA	9	11	13	22	30	65	168	204	205	150	44	5
MHS	MT SHASTA	CA	0	0	0	12	58	169	308	272	134	38	0	0
PRB	PASO ROBLES	CA	0	0	2	16	72	213	319	325	225	65	4	0
RBL	RED BLUFF	CA	0	2	3	53	190	447	581	517	337	106	7	1
RDD	REDDING	CA	0	3	4	51	188	458	610	535	335	90	4	0
SAC	SACRAMENTO	CA	0	5	10	60	154	312	371	349	253	71	0	0
SAN	SAN DIEGO	CA	4	8	15	32	44	91	218	273	261	165	40	2
SFO	SAN FRANCISCO	CA	0	0	2	7	14	35	35	51	75	51	1	0
SCK	STOCKTON	CA	0	0	2	32	119	309	419	392	269	80	3	0
AKO	AKRON	CO	0	0	0	2	23	197	328	267	130	7	2	0
ALS	ALAMOSA	CO	0	0	0	0	0	21	60	18	8	0	0	0
COS	COLORADO SPRINGS	CO	0	0	0	0	14	164	252	199	98	3	0	0
DEN	DENVER	CO	0	0	0	1	23	193	342	284	137	6	0	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
EGE	EAGLE	CO	0	0	0	0	2	57	143	69	14	3	0	0
GJT	GRAND JUNCTION	CO	0	0	0	3	51	313	464	370	154	4	0	0
LHX	LA JUNTA	CO	0	0	2	11	85	355	484	394	224	17	1	0
PUB	PUEBLO	CO	0	0	0	2	49	281	415	335	169	11	2	0
TAD	TRINIDAD	CO	0	0	0	3	34	238	370	290	145	7	0	0
BDR	BRIDGEPORT	CT	0	0	0	1	39	172	371	328	145	25	0	0
BDL	HARTFORD	CT	0	0	0	4	58	161	337	267	102	12	0	0
ILG	WILMINGTON	DE	0	0	3	17	109	282	478	397	226	65	3	0
DCA	WASHINGTON	DC	0	1	5	34	163	360	527	460	268	67	2	0
DAB	DAYTONA BEACH	FL	52	98	154	239	376	509	608	617	539	412	190	134
FLL	FT LAUDERDALE	FL	187	249	299	406	486	570	642	647	588	537	351	306
FMY	FORT MYERS	FL	102	171	221	349	463	533	577	585	532	444	235	190
GNV	GAINESVILLE	FL	41	68	123	200	361	505	582	583	494	326	127	88
JAX	JACKSONVILLE	FL	21	41	86	149	304	462	541	535	429	248	66	46
EYW	KEY WEST	FL	204	259	312	417	499	564	628	638	586	526	353	306
MLB	MELBOURNE	FL	68	120	170	273	393	496	566	576	512	415	203	151
MIA	MIAMI	FL	178	235	288	398	483	554	606	612	561	504	318	274
MCO	ORLANDO	FL	56	113	173	277	406	511	570	579	512	392	166	122
PNS	PENSACOLA	FL	18	33	90	145	349	503	572	554	466	261	58	38
TLH	TALLAHASSEE	FL	16	27	84	144	349	499	565	566	464	255	59	38
TPA	TAMPA	FL	66	118	187	309	462	543	591	602	548	431	191	142
VRB	VERO BEACH	FL	100	152	198	298	412	519	591	599	536	445	260	200
PBI	WEST PALM BEACH	FL	134	205	244	349	439	517	587	600	533	466	286	233
ABY	ALBANY	GA	37	82	155	244	467	617	695	674	553	365	122	76
AHN	ATHENS	GA	1	5	24	59	219	399	509	460	312	101	9	3
ATL	ATLANTA	GA	1	4	28	69	239	403	504	474	343	119	10	4
AGS	AUGUSTA	GA	6	11	36	78	248	427	549	508	355	137	17	10
BQK	BRUNSWICK	GA	16	26	65	123	298	457	547	522	405	214	49	27
CSG	COLUMBUS	GA	5	13	46	94	291	457	554	529	409	173	25	11
MCN	MACON	GA	5	9	35	72	249	430	541	501	358	136	18	10
SAV	SAVANNAH	GA	14	25	68	130	313	475	576	550	416	208	43	26
AYS	WAYCROSS	GA	19	45	110	184	354	502	593	576	442	237	60	46
ITO	HILO-HAWAII	HI	254	227	247	280	328	340	395	410	406	388	315	265
HNL	HONOLULU-OAHU	HI	303	274	304	364	419	465	530	543	512	486	407	343
OGG	KAHULUI-MAUI	HI	256	238	273	334	377	432	496	508	486	458	367	307
LIH	LIHUE-KAUAI	HI	251	212	238	313	361	409	466	499	476	429	353	290
BOI	BOISE	ID	0	0	0	5	40	197	455	375	125	6	0	0
BYI	BURLEY	ID	0	0	0	1	7	88	248	167	37	5	0	0
IDA	IDAHO FALLS	ID	0	0	0	0	2	49	169	110	23	3	0	0
LWS	LEWISTON	ID	0	0	0	3	42	167	402	370	106	4	0	0
PIH	POCATELLO	ID	0	0	0	0	4	80	239	168	36	1	0	0
ORD	CHICAGO	IL	0	0	4	6	74	213	333	294	144	19	1	0
MLI	MOLINE	IL	0	0	3	7	90	259	338	264	149	25	1	0
PIA	PEORIA	IL	0	0	4	10	113	278	368	306	180	32	1	0
UIN	QUINCY	IL	0	0	6	22	133	332	438	366	240	65	7	1
RFD	ROCKFORD	IL	0	0	4	4	72	214	308	239	121	16	1	0
SPI	SPRINGFIELD	IL	0	0	5	17	142	305	375	306	191	43	2	0
EVV	EVANSVILLE	IN	0	1	6	28	164	337	434	377	227	63	3	1
FWA	FORT WAYNE	IN	0	0	3	3	85	216	293	220	111	22	0	0
IND	INDIANAPOLIS	IN	0	1	5	10	117	259	359	316	175	35	1	0
SBN	SOUTH BEND	IN	0	0	4	4	72	188	269	219	113	18	0	0
LAF	WEST LAFAYETTE	IN	0	0	6	8	94	243	289	243	138	28	1	0
BRL	BURLINGTON	IA	0	0	5	22	123	332	419	348	231	62	8	1
CID	CEDAR RAPIDS	IA	0	0	3	5	64	204	269	198	111	14	1	0
DSM	DES MOINES	IA	0	0	4	13	96	300	395	317	176	18	1	0
DBQ	DUBUQUE	IA	0	0	2	3	48	169	243	172	86	10	0	0
MCW	MASON CITY	IA	0	0	1	1	47	184	236	156	82	4	0	0
OTM	OTTUMWA	IA	0	0	3	9	79	250	324	249	145	22	2	0
SUX	SIOUX CITY	IA	0	0	3	5	65	254	326	239	123	4	0	0
SPW	SPENCER	IA	0	0	2	11	83	287	351	259	161	22	2	0
ALO	WATERLOO	IA	0	0	2	4	63	216	290	204	107	9	0	0
CNU	CHANUTE	KS	0	0	8	27	136	373	488	422	256	55	6	0
CNK	CONCORDIA	KS	0	0	4	16	100	361	443	345	223	30	1	0
DDC	DODGE CITY	KS	0	0	3	18	105	366	464	393	245	34	0	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
GCK	GARDEN CITY	KS	0	0	3	11	86	340	426	353	212	24	2	0
GLD	GOODLAND	KS	0	0	0	4	49	255	370	297	160	8	0	0
RSL	RUSSELL	KS	0	0	3	20	103	376	474	383	236	28	0	0
SLN	SALINA	KS	0	0	6	23	137	426	527	422	264	42	4	0
TOP	TOPEKA	KS	0	0	6	19	134	383	470	383	230	40	2	0
ICT	WICHITA	KS	0	0	7	27	148	419	529	447	289	57	3	0
BWG	BOWLING GREEN	KY	0	2	9	39	180	353	465	408	241	66	6	2
JKL	JACKSON	KY	0	2	14	44	156	285	395	354	236	81	9	2
LEX	LEXINGTON	KY	0	1	5	21	138	269	371	326	195	49	3	0
SDF	LOUISVILLE	KY	0	2	11	41	198	368	475	430	266	73	5	1
PAH	PADUCAH	KY	0	1	5	30	169	350	440	379	231	69	4	1
BTR	BATON ROUGE	LA	23	50	122	176	366	531	629	617	505	284	82	62
LFT	LAFAYETTE	LA	19	39	104	167	353	507	576	572	466	246	63	47
LCH	LAKE CHARLES	LA	16	34	100	155	344	511	581	591	484	238	58	36
MLU	MONROE	LA	5	15	57	94	281	476	565	557	423	154	21	20
MSY	NEW ORLEANS	LA	23	52	127	191	389	542	606	603	509	302	72	51
SHV	SHREVEPORT	LA	5	17	58	107	294	499	591	599	452	173	29	22
AUG	AUGUSTA	ME	0	0	0	0	14	69	181	156	52	3	0	0
BGR	BANGOR	ME	0	0	0	0	29	110	226	199	85	8	1	0
CAR	CARIBOU	ME	0	0	0	0	13	41	113	96	21	0	0	0
HUL	HOULTON	ME	0	0	0	0	11	38	101	82	21	0	0	0
PWM	PORTLAND	ME	0	0	0	0	15	72	188	163	53	2	0	0
BWI	BALTIMORE	MD	0	0	2	20	115	281	448	366	196	45	1	0
SBY	SALISBURY	MD	0	0	6	35	138	317	525	435	269	98	11	2
BOS	BOSTON	MA	0	0	1	5	42	156	323	294	118	13	0	0
CHH	CHATHAM	MA	0	0	0	1	20	106	265	259	114	23	2	0
ORH	WORCESTER	MA	0	0	0	5	43	130	291	232	103	17	1	0
APN	ALPENA	MI	0	0	1	0	20	70	152	119	41	3	0	0
DTW	DETROIT	MI	0	0	2	1	73	192	319	268	114	18	0	0
FNT	FLINT	MI	0	0	2	1	57	158	251	198	79	12	1	0
GRR	GRAND RAPIDS	MI	0	0	3	1	57	161	272	211	89	9	0	0
CMX	HANCOCK	MI	0	0	0	0	10	37	103	72	24	1	0	0
HTL	HOUGHTON LAKE	MI	0	0	1	0	36	74	152	104	36	3	0	0
JXN	JACKSON	MI	0	0	1	1	51	141	230	180	82	13	1	0
LAN	LANSING	MI	0	0	2	1	55	152	257	202	81	11	0	0
SAW	MARQUETTE	MI	0	0	0	0	12	45	108	62	23	0	0	0
MKG	MUSKEGON	MI	0	0	3	1	41	128	242	200	82	9	0	0
MBS	SAGINAW	MI	0	0	2	1	56	149	251	191	75	11	0	0
ANJ	SAULT ST MARIE	MI	0	0	0	0	12	40	128	102	32	1	0	0
TVC	TRAVERSE CITY	MI	0	0	3	1	40	104	211	181	74	7	1	0
AXN	ALEXANDRIA	MN	0	0	0	1	34	141	236	158	58	2	0	0
DLH	DULUTH	MN	0	0	0	0	11	47	144	98	24	0	0	0
HIB	HIBBING	MN	0	0	0	0	7	27	72	43	12	0	0	0
INL	INT'L FALLS	MN	0	0	0	0	10	38	92	55	14	0	0	0
MSP	MINNEAPOLIS	MN	0	0	2	2	58	214	329	243	105	4	0	0
RST	ROCHESTER	MN	0	0	2	1	41	153	214	139	71	2	0	0
STC	SAINT CLOUD	MN	0	0	1	1	30	128	216	137	55	1	0	0
GWO	GREENWOOD	MS	5	17	55	104	289	472	584	574	451	214	46	39
JAN	JACKSON	MS	6	19	57	89	262	453	543	530	407	162	23	21
MCB	MCCOMB	MS	10	26	71	100	273	450	531	516	413	187	34	30
MEI	MERIDIAN	MS	5	18	51	78	241	440	534	514	389	151	15	17
TUP	TUPELO	MS	2	5	27	58	233	421	531	497	347	120	14	8
COU	COLUMBIA	MO	0	0	6	24	133	329	426	368	217	47	2	0
JLN	JOPLIN	MO	0	1	11	31	142	364	482	419	258	66	7	1
MCI	KANSAS CITY	MO	0	0	6	18	112	337	427	355	204	36	2	0
STL	SAINT LOUIS	MO	0	0	10	37	195	406	510	440	276	71	4	1
SGF	SPRINGFIELD	MO	0	1	5	22	132	331	447	384	240	54	2	0
BIL	BILLINGS	MT	0	0	0	2	15	126	323	250	79	4	0	0
BTM	BUTTE	MT	0	0	0	1	4	58	166	122	51	11	0	0
CTB	CUT BANK	MT	0	0	0	3	5	54	187	159	51	14	2	0
GGW	GLASGOW	MT	0	0	0	1	19	97	272	219	42	2	0	0
GTF	GREAT FALLS	MT	0	0	1	0	3	41	179	141	32	1	0	0
HVR	HAVRE	MT	0	0	0	0	7	59	214	158	25	0	0	0
HLN	HELENA	MT	0	0	0	0	5	74	248	182	41	1	0	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
FCA	KALISPELL	MT	0	0	0	5	28	86	184	125	28	3	0	0
LWT	LEWISTOWN	MT	0	0	0	0	1	33	148	111	21	2	0	0
MLS	MILES CITY	MT	0	0	1	2	20	135	356	262	74	3	0	0
MSO	MISSOULA	MT	0	0	0	0	2	53	192	140	22	0	0	0
GRI	GRAND ISLAND	NE	0	0	2	9	73	303	376	286	156	9	0	0
LNK	LINCOLN	NE	0	0	3	11	93	320	402	320	181	15	1	0
OFK	NORFOLK	NE	0	0	2	12	61	245	331	246	133	9	0	0
LBF	NORTH PLATTE	NE	0	0	1	4	32	226	346	263	127	2	0	0
OMA	OMAHA	NE	0	0	4	13	98	330	419	338	188	15	0	0
BFF	SCOTTSBLUFF	NE	0	0	0	1	22	205	349	263	106	1	0	0
VTN	VALENTINE	NE	0	0	1	3	35	211	370	277	121	3	0	0
EKO	ELKO	NV	0	0	0	0	5	108	315	215	50	0	0	0
ELY	ELY	NV	0	0	0	0	2	71	172	109	21	0	0	0
LAS	LAS VEGAS	NV	0	3	51	190	401	771	910	857	602	222	26	0
LOL	LOVELOCK	NV	0	0	0	26	95	290	522	421	196	50	3	0
RNO	RENO	NV	0	0	0	4	35	236	436	368	145	8	0	0
TPH	TONOPAH	NV	0	0	0	3	45	234	403	334	113	11	0	0
WMC	WINNEMUCCA	NV	0	0	3	3	23	145	337	236	58	0	0	0
CON	CONCORD	NH	0	0	0	2	30	99	245	174	65	3	0	0
LEB	LEBANON	NH	0	0	1	2	63	155	283	231	111	24	1	0
MWN	MT WASHINGTON	NH	0	0	0	0	0	0	0	0	0	0	0	0
ACY	ATLANTIC CITY	NJ	0	0	1	11	80	226	404	335	171	35	2	0
EWR	NEWARK	NJ	0	0	1	11	90	258	450	385	192	36	1	0
ABQ	ALBUQUERQUE	NM	0	0	0	10	101	400	457	397	222	19	0	0
CNM	CARLSBAD	NM	0	1	16	80	260	520	575	535	311	89	9	3
CAO	CLAYTON	NM	0	0	1	8	60	268	357	288	162	18	3	0
GUP	GALLUP	NM	0	0	0	0	5	124	238	172	43	0	0	0
ROW	ROSWELL	NM	0	0	10	60	233	500	567	526	301	70	2	0
CVN	TUCUMCARI	NM	0	2	4	18	116	356	397	367	185	30	2	1
ALB	ALBANY	NY	0	0	0	4	55	142	280	208	84	6	0	0
BGM	BINGHAMTON	NY	0	0	0	1	36	77	176	123	58	5	0	0
BUF	BUFFALO	NY	0	0	1	1	54	121	252	213	91	12	0	0
GFL	GLENS FALLS	NY	0	0	0	2	48	124	267	193	87	17	0	0
MSS	MASSENA	NY	0	0	0	1	27	82	177	139	43	1	0	0
LGA	NEW YORK	NY	0	0	1	7	86	269	467	420	218	46	2	0
ROC	ROCHESTER	NY	0	0	1	2	56	129	249	199	86	12	0	0
SYR	SYRACUSE	NY	0	0	0	2	57	129	269	214	88	10	0	0
UCA	UTICA	NY	0	0	6	25	245	412	584	513	282	75	2	0
ART	WATERTOWN	NY	0	0	0	1	29	77	179	149	51	8	0	0
AVL	ASHEVILLE	NC	0	1	1	11	87	223	323	272	161	32	1	0
HAT	CAPE HATTERAS	NC	29	49	114	243	453	632	769	719	595	414	123	76
CLT	CHARLOTTE	NC	0	4	18	49	195	371	496	437	280	78	4	2
GSO	GREENSBORO	NC	0	2	10	35	166	326	455	383	230	55	2	2
HKY	HICKORY	NC	0	2	16	45	172	343	483	423	276	101	15	8
EWN	NEW BERN	NC	3	7	22	62	217	381	507	462	322	120	14	14
RDU	RALEIGH DURHAM	NC	0	3	17	49	192	353	494	430	261	76	4	5
ILM	WILMINGTON	NC	5	6	27	67	223	386	509	464	330	133	19	14
BIS	BISMARCK	ND	0	0	0	0	23	132	266	174	49	2	0	0
P11	DEVIL'S LAKE	ND	0	0	0	2	86	258	385	301	132	12	0	0
DIK	DICKINSON	ND	0	0	0	1	14	47	173	127	34	3	0	0
FAR	FARGO	ND	0	0	1	0	40	153	249	157	59	4	0	0
GFK	GRAND FORKS	ND	0	0	0	1	40	151	274	200	80	14	0	0
JMS	JAMESTOWN	ND	0	0	0	0	21	119	215	118	35	3	0	0
MOT	MINOT	ND	0	0	0	0	24	102	223	171	41	2	0	0
ISN	WILLISTON	ND	0	0	0	4	46	174	334	267	93	14	0	0
CAK	AKRON CANTON	OH	0	1	2	7	88	189	305	255	130	28	1	0
CLE	CLEVELAND	OH	0	0	2	6	85	192	305	254	135	31	1	0
CMH	COLUMBUS	OH	0	1	3	11	125	251	351	308	160	37	1	0
CVG	CINCINNATI	OH	0	1	4	15	125	256	362	321	179	40	2	0
DAY	DAYTON	OH	0	0	3	9	115	240	327	278	155	33	1	0
FDY	FINDLAY	OH	0	0	3	7	99	233	323	256	141	31	2	0
MFD	MANSFIELD	OH	0	0	2	9	90	207	326	272	157	46	2	0
TOL	TOLEDO	OH	0	0	2	3	75	196	297	241	119	23	1	0
YNG	YOUNGSTOWN	OH	0	0	1	5	69	141	237	184	90	20	1	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
LHQ	ZANESVILLE	OH	0	1	1	7	97	204	277	230	120	27	1	0
GAG	GAGE	OK	0	3	21	56	187	458	610	549	380	110	23	2
HBR	HOBART	OK	0	1	13	49	213	471	605	570	373	106	12	2
MLC	MCALESTER	OK	1	4	27	64	188	424	544	513	352	111	16	6
OKC	OKLAHOMA CITY	OK	0	2	16	40	163	396	536	495	319	83	5	1
PNC	PONCA CITY	OK	0	10	48	113	272	565	708	672	506	208	43	4
TUL	TULSA	OK	0	3	19	49	194	455	571	516	350	95	7	2
AST	ASTORIA	OR	0	0	0	1	2	6	5	14	11	0	0	0
BKE	BAKER	OR	0	0	0	0	5	36	135	108	21	1	0	0
BNO	BURNS	OR	0	0	0	0	3	49	168	113	20	0	0	0
EUG	EUGENE	OR	0	0	0	0	4	54	143	168	45	3	0	0
MFR	MEDFORD	OR	0	0	0	6	49	181	389	359	147	11	0	0
OTH	NORTH BEND	OR	0	0	0	12	29	69	100	106	76	31	6	1
PDT	PENDLETON	OR	0	0	0	1	24	123	313	269	66	3	0	0
PDX	PORTLAND	OR	0	0	0	4	27	94	201	232	82	3	0	0
RDM	REDMOND	OR	0	0	0	2	13	96	240	206	76	16	0	0
SLE	SALEM	OR	0	0	0	1	14	77	185	203	62	2	0	0
ABE	ALLENTOWN	PA	0	0	0	7	73	193	352	274	127	19	0	0
AOO	ALTOONA	PA	0	0	0	6	62	124	225	180	82	25	1	0
BFD	BRADFORD	PA	0	0	0	0	28	52	119	83	37	6	0	0
DUJ	DU BOIS	PA	0	0	0	3	48	98	192	146	64	13	0	0
ERI	ERIE	PA	0	0	1	3	68	151	262	235	116	25	1	0
CXY	HARRISBURG	PA	0	0	1	11	100	243	419	336	169	37	1	0
PHL	PHILADELPHIA	PA	0	0	1	15	108	286	473	401	210	45	1	0
PIT	PITTSBURGH	PA	0	1	1	9	87	180	289	232	118	24	1	0
AVP	SCRANTON	PA	0	0	0	5	68	147	301	231	107	15	0	0
IPT	WILLIAMSPORT	PA	0	0	0	4	70	164	321	254	112	19	0	0
PVD	PROVIDENCE	RI	0	0	0	2	41	144	327	282	107	13	0	0
CHS	CHARLESTON	SC	9	14	48	111	295	454	562	528	397	183	34	19
CAE	COLUMBIA	SC	5	11	40	99	279	462	581	530	376	142	15	9
FLO	FLORENCE	SC	5	11	36	87	264	445	559	497	353	135	19	12
GSP	GREENVILLE	SC	0	3	16	45	187	364	473	415	281	71	4	2
ABR	ABERDEEN	SD	0	0	1	0	36	166	259	164	64	3	0	0
HON	HURON	SD	0	0	2	2	41	194	303	212	101	3	0	0
PIR	PIERRE	SD	0	0	1	7	51	232	461	356	190	31	2	0
RAP	RAPID CITY	SD	0	0	0	1	10	110	267	190	71	3	0	0
FSD	SIOUX FALLS	SD	0	0	1	4	41	212	306	221	103	4	1	0
ATY	WATERTOWN	SD	0	0	1	0	27	140	229	147	61	1	0	0
TRI	BRISTOL	TN	1	2	7	29	135	290	424	371	241	82	7	1
CHA	CHATTANOOGA	TN	0	3	14	51	216	400	502	465	319	96	7	2
CSV	CROSSVILLE	TN	0	2	11	36	126	250	388	341	221	84	9	4
MKL	JACKSON	TN	0	2	11	46	189	364	465	410	268	116	18	5
TYS	KNOXVILLE	TN	0	2	9	36	178	331	435	394	256	67	4	1
MEM	MEMPHIS	TN	1	4	23	66	254	454	556	529	383	124	12	6
BNA	NASHVILLE	TN	0	3	13	49	209	391	503	449	291	87	8	2
ABI	ABILENE	TX	1	9	46	116	282	486	607	609	395	168	21	7
ALI	ALICE	TX	46	89	186	288	462	591	664	678	540	369	141	79
AMA	AMARILLO	TX	0	1	7	28	135	360	467	429	240	48	2	0
AUS	AUSTIN	TX	7	28	82	150	337	535	629	650	477	231	60	25
BRO	BROWNSVILLE	TX	71	134	231	361	516	611	649	686	560	426	215	132
CLL	COLLEGE STATION	TX	19	42	115	188	378	577	699	731	561	316	109	67
CRP	CORPUS CHRISTI	TX	38	82	176	278	440	576	629	661	542	362	140	74
DHT	DALHART	TX	0	0	6	25	122	384	530	466	279	78	19	3
DFW	DALLAS FT WORTH	TX	3	12	53	115	300	539	661	662	477	196	29	13
DRT	DEL RIO	TX	6	34	136	272	455	626	725	736	531	300	69	19
ELP	EL PASO	TX	0	2	32	143	339	626	632	590	390	150	8	0
GLS	GALVESTON	TX	17	33	115	215	409	567	633	658	546	364	123	57
IAH	HOUSTON	TX	19	44	112	183	378	549	629	642	487	263	73	47
LRD	LAREDO	TX	36	98	232	370	545	687	758	777	588	411	159	72
LBB	LUBBOCK	TX	0	1	18	61	216	442	526	491	283	79	5	0
LFK	LUFKIN	TX	8	22	73	134	313	503	576	588	439	194	42	27
MFE	MCALLEN	TX	80	158	284	410	559	665	732	770	619	460	218	128
MAF	MIDLAND ODESSA	TX	0	5	46	131	322	532	602	591	372	156	14	1
PSX	PALACIOS	TX	21	44	120	212	409	561	626	641	500	306	107	56

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
CXO	PORT ARTHUR	TX	12	31	81	132	315	489	567	583	427	197	51	32
SJT	SAN ANGELO	TX	2	9	60	145	322	534	626	621	399	172	25	7
SAT	SAN ANTONIO	TX	9	33	100	192	377	553	653	685	505	280	71	27
VCT	VICTORIA	TX	23	52	125	206	398	560	626	652	502	292	92	48
ACT	WACO	TX	3	11	49	113	303	533	647	657	465	203	34	15
SPS	WICHITA FALLS	TX	1	4	27	72	245	477	603	591	388	129	11	4
CDC	CEDAR CITY	UT	0	0	0	4	13	168	310	239	72	1	0	0
SLC	SALT LAKE CITY	UT	0	0	1	6	63	313	553	462	191	9	0	0
BTV	BURLINGTON	VT	0	0	1	2	49	126	255	214	80	6	0	0
MPV	MONTPELIER	VT	0	0	0	1	16	51	119	87	29	2	0	0
LYH	LYNCHBURG	VA	0	0	3	22	114	250	392	323	176	40	2	0
ORF	NORFOLK	VA	1	2	15	51	182	368	522	451	291	96	9	4
RIC	RICHMOND	VA	0	1	8	38	169	332	487	416	249	65	4	1
ROA	ROANOKE	VA	0	0	5	27	143	277	422	346	195	46	3	0
BLI	BELLINGHAM	WA	0	0	0	0	1	20	43	51	7	0	0	0
HQM	HOQUIAM	WA	0	0	0	1	2	10	5	18	12	0	0	0
OLM	OLYMPIA	WA	0	0	0	0	3	32	61	74	12	0	0	0
UIL	QUILLAYUTE	WA	0	0	0	0	1	11	4	20	7	0	0	0
SEA	SEATTLE TACOMA	WA	0	0	1	2	13	51	117	136	37	0	0	0
GEG	SPOKANE	WA	0	0	0	1	19	97	269	234	47	1	0	0
ALW	WALLA WALLA	WA	0	0	1	16	93	248	506	462	189	39	1	0
EAT	WENATCHEE	WA	0	0	0	2	55	170	386	341	85	10	0	0
YKM	YAKIMA	WA	0	0	0	2	47	153	338	271	56	1	0	0
BKW	BECKLEY	WV	0	0	3	11	69	136	232	186	97	18	0	0
CRW	CHARLESTON	WV	1	1	6	23	130	238	359	314	176	41	1	0
EKN	ELKINS	WV	0	0	1	2	42	111	202	154	79	13	0	0
HTS	HUNTINGTON	WV	1	1	7	25	133	251	356	308	180	44	2	0
MRB	MARTINSBURG	WV	0	1	1	14	93	219	360	290	143	29	0	0
MGW	MORGANTOWN	WV	0	1	4	17	111	201	319	267	151	37	2	0
PKB	PARKERSBURG	WV	0	1	4	17	143	238	371	300	179	41	1	0
EAU	EAU CLAIRE	WI	0	0	1	1	36	135	229	155	63	2	0	0
GRB	GREEN BAY	WI	0	0	1	1	36	124	215	145	56	4	0	0
LSE	LACROSSE	WI	0	0	2	5	70	226	332	253	117	11	0	0
MSN	MADISON	WI	0	0	3	2	51	163	259	186	77	7	0	0
MKE	MILWAUKEE	WI	0	0	1	1	41	144	279	238	106	13	1	0
AUW	WAUSAU	WI	0	0	1	1	32	107	197	131	50	3	0	0
CPR	CASPER	WY	0	0	0	0	4	76	225	155	45	1	0	0
CYS	CHEYENNE	WY	0	0	0	0	3	81	198	150	54	0	0	0
COD	CODY	WY	0	0	0	1	6	70	220	146	50	8	0	0
LND	LANDER	WY	0	0	0	0	6	93	252	245	84	0	0	0
RKS	ROCK SPRINGS	WY	0	0	0	0	2	69	198	125	24	0	0	0
SHR	SHERIDAN	WY	0	0	0	0	4	69	237	174	46	1	0	0
WRL	WORLAND	WY	0	0	0	0	12	132	292	217	45	4	0	0

Table 7C.3.4 Weather Station Monthly Heating Degree Day Data Fractions (10-Year Average, 2012-2021)

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	26%	19%	11%	4%	1%	0%	0%	0%	0%	3%	15%	20%
HSV	HUNTSVILLE	AL	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	15%	19%
MOB	MOBILE	AL	29%	18%	10%	3%	0%	0%	0%	0%	0%	2%	15%	22%
MGM	MONTGOMERY	AL	28%	18%	11%	3%	0%	0%	0%	0%	0%	2%	16%	21%
MSL	MUSCLE SHOALS	AL	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	15%	19%
TCL	TUSCALOOSA	AL	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	16%	20%
ANC	ANCHORAGE	AK	15%	13%	13%	8%	5%	2%	1%	2%	5%	8%	13%	14%
BRW	BARROW	AK	13%	12%	13%	10%	7%	5%	4%	4%	5%	7%	9%	12%
BET	BETHEL	AK	15%	12%	13%	9%	5%	3%	2%	3%	5%	8%	12%	14%
BTT	BETTLES	AK	16%	13%	13%	8%	4%	1%	1%	2%	5%	8%	13%	15%
BIG	BIG DELTA	AK	16%	13%	12%	8%	4%	2%	1%	2%	5%	9%	14%	15%
CDB	COLD BAY	AK	12%	10%	12%	10%	8%	6%	4%	4%	5%	8%	10%	11%
CDV	CORDOVA	AK	13%	11%	12%	9%	7%	4%	3%	4%	5%	8%	11%	12%
FAI	FAIRBANKS	AK	17%	14%	13%	7%	3%	1%	1%	2%	4%	8%	14%	16%
GKN	GULKANA	AK	16%	13%	12%	7%	4%	2%	1%	2%	5%	9%	14%	15%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
HOM	HOMER	AK	14%	12%	12%	9%	6%	4%	3%	3%	5%	8%	11%	13%
JNU	JUNEAU	AK	13%	12%	12%	9%	6%	4%	3%	3%	5%	9%	12%	13%
ENA	KENAI	AK	15%	12%	12%	8%	6%	3%	2%	3%	5%	8%	12%	14%
KTN	KETCHIKAN	AK	13%	12%	12%	9%	6%	4%	2%	2%	5%	8%	11%	14%
AKN	KING SALMON	AK	15%	11%	13%	8%	6%	3%	2%	3%	5%	8%	12%	14%
ADQ	KODIAK	AK	13%	11%	12%	10%	7%	5%	3%	3%	5%	8%	11%	12%
OTZ	KOTZEBUE	AK	14%	13%	14%	10%	6%	3%	2%	2%	5%	7%	11%	13%
MCG	MCGRATH	AK	17%	13%	13%	8%	4%	1%	1%	2%	5%	8%	13%	15%
OME	NOME	AK	14%	12%	13%	9%	6%	3%	3%	3%	5%	7%	11%	13%
ORT	NORTHWAY	AK	16%	14%	12%	7%	4%	2%	1%	2%	4%	8%	14%	16%
SNP	ST PAUL ISLAND	AK	12%	11%	12%	10%	8%	6%	5%	4%	5%	7%	9%	11%
SIT	SITKA	AK	12%	12%	12%	10%	7%	5%	3%	3%	5%	8%	11%	12%
TKA	TALKEETNA	AK	15%	13%	13%	8%	5%	2%	1%	2%	5%	9%	13%	14%
UNK	UNALAKLEET	AK	14%	12%	13%	9%	6%	3%	2%	3%	5%	8%	12%	13%
VWS	VALDEZ	AK	17%	14%	13%	8%	4%	1%	1%	1%	4%	8%	13%	15%
YAK	YAKUTAT	AK	13%	12%	12%	9%	7%	4%	3%	3%	5%	8%	11%	13%
DUG	DOUGLAS	AZ	26%	17%	11%	5%	1%	0%	0%	0%	0%	3%	13%	24%
FLG	FLAGSTAFF	AZ	17%	14%	12%	9%	6%	1%	0%	1%	3%	7%	12%	17%
PHX	PHOENIX	AZ	33%	19%	6%	0%	0%	0%	0%	0%	0%	0%	7%	34%
TUS	TUCSON	AZ	30%	20%	9%	2%	0%	0%	0%	0%	0%	1%	9%	30%
INW	WINSLOW	AZ	22%	16%	12%	6%	2%	0%	0%	0%	0%	6%	14%	22%
NYL	YUMA	AZ	31%	19%	7%	1%	0%	0%	0%	0%	0%	0%	6%	36%
ELD	EL DORADO	AR	25%	20%	11%	5%	1%	0%	0%	0%	0%	4%	15%	20%
FYV	FAYETTEVILLE	AR	22%	18%	12%	6%	2%	0%	0%	0%	0%	6%	14%	19%
FSM	FORT SMITH	AR	25%	20%	11%	5%	1%	0%	0%	0%	0%	4%	14%	21%
HRO	HARRISON	AR	23%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
LIT	LITTLE ROCK	AR	25%	19%	11%	4%	1%	0%	0%	0%	0%	4%	15%	21%
TXK	TEXARKANA	AR	25%	20%	11%	5%	1%	0%	0%	0%	0%	4%	14%	21%
BFL	BAKERSFIELD	CA	25%	17%	10%	4%	1%	0%	0%	0%	0%	2%	13%	27%
BLH	BLYTHE	CA	32%	18%	6%	0%	0%	0%	0%	0%	0%	1%	10%	33%
EKA	EUREKA	CA	11%	11%	11%	9%	8%	6%	5%	5%	5%	7%	9%	12%
FAT	FRESNO	CA	25%	17%	11%	4%	1%	0%	0%	0%	0%	2%	13%	27%
IPL	IMPERIAL	CA	31%	19%	7%	1%	0%	0%	0%	0%	0%	1%	8%	34%
LAX	LOS ANGELES	CA	20%	19%	16%	9%	6%	1%	0%	0%	0%	1%	7%	21%
MHS	MT SHASTA	CA	17%	15%	14%	9%	4%	1%	0%	0%	2%	7%	12%	18%
PRB	PASO ROBLES	CA	20%	17%	14%	7%	3%	0%	0%	0%	0%	4%	13%	22%
RBL	RED BLUFF	CA	23%	16%	14%	6%	1%	0%	0%	0%	0%	3%	14%	24%
RDD	REDDING	CA	22%	16%	14%	6%	1%	0%	0%	0%	0%	3%	14%	24%
SAC	SACRAMENTO	CA	23%	16%	12%	6%	2%	0%	0%	0%	0%	3%	14%	25%
SAN	SAN DIEGO	CA	23%	20%	15%	7%	3%	1%	0%	0%	0%	1%	7%	24%
SFO	SAN FRANCISCO	CA	18%	14%	12%	9%	7%	3%	2%	1%	2%	3%	10%	18%
SCK	STOCKTON	CA	23%	17%	12%	6%	1%	0%	0%	0%	0%	3%	14%	24%
AKO	AKRON	CO	18%	17%	12%	9%	5%	0%	0%	0%	1%	8%	12%	18%
ALS	ALAMOSA	CO	19%	14%	11%	8%	5%	1%	0%	1%	3%	8%	12%	18%
COS	COLORADO SPRINGS	CO	18%	16%	12%	9%	5%	0%	0%	0%	1%	8%	13%	18%
DEN	DENVER	CO	18%	17%	12%	9%	5%	0%	0%	0%	1%	7%	12%	18%
EGE	EAGLE	CO	18%	14%	12%	9%	5%	1%	0%	0%	2%	8%	12%	18%
GJT	GRAND JUNCTION	CO	22%	15%	11%	7%	3%	0%	0%	0%	1%	7%	13%	21%
LHX	LA JUNTA	CO	20%	18%	12%	7%	3%	0%	0%	0%	1%	6%	13%	20%
PUB	PUEBLO	CO	19%	17%	12%	8%	3%	0%	0%	0%	1%	7%	13%	19%
TAD	TRINIDAD	CO	19%	16%	12%	9%	4%	0%	0%	0%	1%	7%	13%	19%
BDR	BRIDGEPORT	CT	20%	18%	15%	9%	3%	0%	0%	0%	1%	4%	12%	16%
BDL	HARTFORD	CT	20%	17%	15%	8%	3%	1%	0%	0%	1%	6%	12%	17%
ILG	WILMINGTON	DE	22%	19%	15%	7%	2%	0%	0%	0%	1%	4%	12%	17%
DCA	WASHINGTON	DC	23%	19%	14%	6%	2%	0%	0%	0%	0%	4%	13%	18%
DAB	DAYTONA BEACH	FL	38%	19%	14%	1%	0%	0%	0%	0%	0%	1%	9%	17%
FLL	FT LAUDERDALE	FL	49%	21%	10%	0%	0%	0%	0%	0%	0%	0%	5%	14%
FMY	FORT MYERS	FL	47%	19%	10%	0%	0%	0%	0%	0%	0%	1%	6%	18%
GNV	GAINESVILLE	FL	34%	19%	13%	2%	0%	0%	0%	0%	0%	2%	12%	18%
JAX	JACKSONVILLE	FL	31%	19%	13%	3%	0%	0%	0%	0%	0%	2%	13%	20%
EYW	KEY WEST	FL	53%	22%	7%	0%	0%	0%	0%	0%	0%	0%	0%	17%
MLB	MELBOURNE	FL	39%	19%	14%	1%	0%	0%	0%	0%	0%	1%	8%	18%
MIA	MIAMI	FL	47%	22%	8%	0%	0%	0%	0%	0%	0%	0%	5%	19%
MCO	ORLANDO	FL	41%	18%	11%	1%	0%	0%	0%	0%	0%	1%	9%	19%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
PNS	PENSACOLA	FL	32%	18%	10%	2%	0%	0%	0%	0%	0%	1%	14%	22%
TLH	TALLAHASSEE	FL	31%	18%	11%	3%	0%	0%	0%	0%	0%	2%	14%	21%
TPA	TAMPA	FL	43%	19%	11%	0%	0%	0%	0%	0%	0%	0%	8%	18%
VRB	VERO BEACH	FL	38%	20%	16%	1%	0%	0%	0%	0%	0%	1%	8%	16%
PBI	WEST PALM BEACH	FL	43%	20%	13%	0%	0%	0%	0%	0%	0%	1%	5%	19%
ABY	ALBANY	GA	33%	20%	11%	2%	0%	0%	0%	0%	0%	2%	13%	19%
AHN	ATHENS	GA	25%	18%	12%	5%	1%	0%	0%	0%	0%	4%	15%	20%
ATL	ATLANTA	GA	26%	19%	12%	4%	1%	0%	0%	0%	0%	3%	15%	20%
AGS	AUGUSTA	GA	26%	18%	12%	4%	1%	0%	0%	0%	0%	3%	16%	20%
BQK	BRUNSWICK	GA	29%	19%	13%	4%	0%	0%	0%	0%	0%	2%	14%	20%
CSG	COLUMBUS	GA	28%	19%	11%	3%	1%	0%	0%	0%	0%	2%	15%	21%
MCN	MACON	GA	26%	18%	12%	4%	1%	0%	0%	0%	0%	3%	16%	20%
SAV	SAVANNAH	GA	29%	19%	12%	3%	0%	0%	0%	0%	0%	2%	15%	20%
AYS	WAYCROSS	GA	30%	18%	11%	3%	0%	0%	0%	0%	0%	2%	15%	21%
ITO	HILO-HAWAII	HI	0%	1%	49%	49%	0%	0%	0%	0%	0%	0%	0%	0%
HNL	HONOLULU-OAHU	HI	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
OGG	KAHULUI-MAUI	HI	0%	0%	71%	0%	0%	0%	0%	0%	0%	0%	29%	0%
LIH	LIHUE-KAUAI	HI	38%	3%	0%	0%	0%	0%	0%	0%	0%	0%	59%	0%
BOI	BOISE	ID	20%	15%	11%	7%	3%	1%	0%	0%	1%	7%	14%	20%
BYI	BURLEY	ID	18%	14%	12%	8%	5%	1%	0%	0%	2%	8%	13%	18%
IDA	IDAHO FALLS	ID	18%	15%	11%	8%	5%	1%	0%	0%	3%	8%	12%	18%
LWS	LEWISTON	ID	18%	16%	13%	8%	3%	1%	0%	0%	1%	8%	14%	19%
PIH	POCATELLO	ID	18%	14%	11%	8%	5%	1%	0%	0%	2%	8%	13%	18%
ORD	CHICAGO	IL	21%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	17%
MLI	MOLINE	IL	21%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
PIA	PEORIA	IL	22%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
UIN	QUINCY	IL	22%	19%	13%	7%	2%	0%	0%	0%	1%	5%	13%	18%
RFD	ROCKFORD	IL	21%	19%	13%	8%	3%	0%	0%	0%	1%	6%	13%	17%
SPI	SPRINGFIELD	IL	22%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
EVV	EVANSVILLE	IN	22%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
FWA	FORT WAYNE	IN	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
IND	INDIANAPOLIS	IN	22%	18%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
SBN	SOUTH BEND	IN	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
LAF	WEST LAFAYETTE	IN	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	13%	17%
BRL	BURLINGTON	IA	22%	19%	13%	7%	2%	0%	0%	0%	1%	5%	12%	18%
CID	CEDAR RAPIDS	IA	20%	18%	13%	7%	3%	0%	0%	0%	1%	7%	13%	17%
DSM	DES MOINES	IA	21%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	18%
DBQ	DUBUQUE	IA	20%	18%	13%	8%	3%	0%	0%	0%	2%	6%	12%	17%
MCW	MASON CITY	IA	20%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
OTM	OTTUMWA	IA	21%	19%	13%	7%	3%	0%	0%	0%	1%	6%	13%	18%
SUX	SIOUX CITY	IA	20%	18%	12%	7%	3%	0%	0%	0%	1%	7%	13%	18%
SPW	SPENCER	IA	20%	19%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
ALO	WATERLOO	IA	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	13%	17%
CNU	CHANUTE	KS	22%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
CNK	CONCORDIA	KS	21%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	19%
DDC	DODGE CITY	KS	20%	18%	12%	7%	3%	0%	0%	0%	1%	6%	13%	20%
GCK	GARDEN CITY	KS	20%	18%	12%	8%	3%	0%	0%	0%	1%	6%	13%	20%
GLD	GOODLAND	KS	19%	17%	12%	8%	4%	0%	0%	0%	1%	7%	13%	19%
RSL	RUSSELL	KS	21%	18%	12%	7%	3%	0%	0%	0%	1%	6%	13%	20%
SLN	SALINA	KS	22%	19%	12%	7%	2%	0%	0%	0%	0%	6%	13%	20%
TOP	TOPEKA	KS	22%	19%	12%	6%	2%	0%	0%	0%	1%	6%	13%	19%
ICT	WICHITA	KS	22%	19%	12%	6%	2%	0%	0%	0%	0%	5%	13%	20%
BWG	BOWLING GREEN	KY	23%	18%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
JKL	JACKSON	KY	23%	19%	13%	6%	2%	0%	0%	0%	1%	5%	13%	18%
LEX	LEXINGTON	KY	22%	18%	13%	7%	2%	0%	0%	0%	1%	5%	14%	17%
SDF	LOUISVILLE	KY	23%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
PAH	PADUCAH	KY	22%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
BTR	BATON ROUGE	LA	31%	19%	9%	3%	0%	0%	0%	0%	0%	2%	15%	21%
LFT	LAFAYETTE	LA	31%	19%	9%	3%	0%	0%	0%	0%	0%	2%	14%	22%
LCH	LAKE CHARLES	LA	31%	19%	9%	2%	0%	0%	0%	0%	0%	2%	14%	23%
MLU	MONROE	LA	26%	20%	10%	4%	0%	0%	0%	0%	0%	3%	15%	21%
MSY	NEW ORLEANS	LA	33%	19%	9%	2%	0%	0%	0%	0%	0%	1%	14%	22%
SHV	SHREVEPORT	LA	27%	20%	10%	4%	0%	0%	0%	0%	0%	3%	14%	22%
AUG	AUGUSTA	ME	19%	16%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BGR	BANGOR	ME	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	11%	16%
CAR	CARIBOU	ME	18%	16%	14%	9%	4%	2%	0%	1%	3%	7%	11%	16%
HUL	HOULTON	ME	17%	16%	14%	9%	5%	2%	1%	1%	3%	7%	11%	15%
PWM	PORTLAND	ME	18%	16%	14%	9%	5%	1%	0%	0%	2%	6%	12%	16%
BWI	BALTIMORE	MD	22%	18%	15%	7%	2%	0%	0%	0%	1%	5%	13%	17%
SBY	SALISBURY	MD	23%	19%	15%	8%	2%	0%	0%	0%	0%	4%	12%	17%
BOS	BOSTON	MA	20%	17%	15%	9%	4%	1%	0%	0%	1%	5%	12%	16%
CHH	CHATHAM	MA	19%	17%	16%	10%	5%	1%	0%	0%	1%	5%	11%	15%
ORH	WORCESTER	MA	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	12%	16%
APN	ALPENA	MI	18%	16%	14%	10%	5%	1%	0%	0%	2%	7%	11%	15%
DTW	DETROIT	MI	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
FNT	FLINT	MI	19%	18%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
GRR	GRAND RAPIDS	MI	19%	18%	14%	9%	3%	0%	0%	0%	1%	6%	12%	16%
CMX	HANCOCK	MI	17%	16%	14%	10%	5%	2%	1%	1%	3%	7%	11%	15%
HTL	HOUGHTON LAKE	MI	18%	17%	14%	9%	4%	1%	0%	1%	3%	7%	11%	15%
JXN	JACKSON	MI	19%	17%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
LAN	LANSING	MI	19%	18%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
SAW	MARQUETTE	MI	17%	16%	13%	10%	5%	2%	1%	1%	3%	7%	11%	15%
MKG	MUSKEGON	MI	19%	18%	14%	9%	4%	1%	0%	0%	1%	6%	12%	16%
MBS	SAGINAW	MI	19%	18%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
ANJ	SAULT ST MARIE	MI	18%	16%	14%	10%	5%	2%	0%	0%	2%	7%	11%	15%
TVC	TRAVERSE CITY	MI	18%	17%	14%	10%	5%	1%	0%	0%	2%	6%	11%	15%
AXN	ALEXANDRIA	MN	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	18%
DLH	DULUTH	MN	18%	16%	13%	9%	4%	1%	0%	1%	2%	7%	12%	16%
HIB	HIBBING	MN	18%	16%	12%	8%	5%	2%	1%	1%	3%	7%	12%	16%
INL	INT'L FALLS	MN	18%	16%	12%	8%	4%	1%	0%	1%	3%	7%	11%	16%
MSP	MINNEAPOLIS	MN	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	12%	18%
RST	ROCHESTER	MN	20%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
STC	SAINT CLOUD	MN	19%	17%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
GWO	GREENWOOD	MS	27%	20%	11%	4%	1%	0%	0%	0%	0%	4%	14%	20%
JAN	JACKSON	MS	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	15%	21%
MCB	MCCOMB	MS	28%	19%	10%	4%	1%	0%	0%	0%	0%	2%	15%	21%
MEI	MERIDIAN	MS	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	16%	20%
TUP	TUPELO	MS	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	15%	20%
COU	COLUMBIA	MO	22%	19%	12%	6%	2%	0%	0%	0%	0%	6%	13%	19%
JLN	JOPLIN	MO	22%	19%	12%	6%	2%	0%	0%	0%	0%	6%	13%	19%
MCI	KANSAS CITY	MO	22%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	19%
STL	SAINT LOUIS	MO	23%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
SGF	SPRINGFIELD	MO	22%	19%	12%	6%	2%	0%	0%	0%	0%	6%	13%	19%
BIL	BILLINGS	MT	17%	17%	12%	8%	4%	1%	0%	0%	2%	8%	12%	18%
BTM	BUTTE	MT	16%	15%	12%	9%	6%	3%	1%	1%	3%	8%	12%	16%
CTB	CUT BANK	MT	15%	16%	13%	9%	5%	2%	0%	1%	3%	8%	12%	16%
GGW	GLASGOW	MT	18%	17%	12%	8%	4%	1%	0%	0%	2%	8%	13%	18%
GTF	GREAT FALLS	MT	15%	16%	12%	9%	5%	2%	0%	1%	3%	8%	12%	16%
HVR	HAVRE	MT	17%	16%	12%	8%	4%	1%	0%	0%	3%	8%	13%	17%
HLN	HELENA	MT	17%	16%	12%	8%	5%	1%	0%	0%	3%	8%	13%	17%
FCA	KALISPELL	MT	17%	15%	11%	7%	4%	2%	0%	1%	4%	9%	13%	17%
LWT	LEWISTOWN	MT	15%	16%	12%	9%	6%	2%	0%	1%	3%	8%	12%	16%
MLS	MILES CITY	MT	18%	17%	12%	8%	4%	1%	0%	0%	2%	8%	13%	18%
MSO	MISSOULA	MT	17%	15%	12%	8%	5%	2%	0%	0%	3%	9%	13%	17%
GRI	GRAND ISLAND	NE	20%	18%	12%	7%	3%	0%	0%	0%	1%	7%	12%	19%
LNK	LINCOLN	NE	21%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	19%
OFK	NORFOLK	NE	20%	18%	12%	7%	3%	0%	0%	0%	1%	7%	12%	18%
LBF	NORTH PLATTE	NE	19%	17%	12%	8%	4%	0%	0%	0%	1%	8%	13%	18%
OMA	OMAHA	NE	21%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	19%
BFF	SCOTTSBLUFF	NE	18%	17%	12%	8%	4%	0%	0%	0%	1%	8%	13%	18%
VTN	VALENTINE	NE	18%	17%	12%	8%	4%	0%	0%	0%	1%	7%	12%	18%
EKO	ELKO	NV	18%	14%	12%	8%	5%	1%	0%	0%	2%	8%	13%	18%
ELY	ELY	NV	17%	14%	12%	9%	6%	1%	0%	0%	3%	8%	12%	17%
LAS	LAS VEGAS	NV	28%	18%	8%	2%	0%	0%	0%	0%	0%	1%	12%	30%
LOL	LOVELOCK	NV	19%	15%	12%	7%	3%	1%	0%	0%	2%	7%	13%	20%
RNO	RENO	NV	19%	15%	13%	8%	4%	1%	0%	0%	1%	7%	14%	20%
TPH	TONOPAH	NV	19%	16%	13%	8%	3%	0%	0%	0%	1%	7%	13%	20%
WMC	WINNEMUCCA	NV	17%	14%	12%	9%	5%	1%	0%	0%	2%	9%	13%	19%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
CON	CONCORD	NH	19%	16%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%
LEB	LEBANON	NH	19%	17%	15%	9%	3%	1%	0%	0%	2%	6%	12%	16%
MWN	MT WASHINGTON	NH	14%	13%	12%	10%	6%	4%	3%	4%	5%	7%	10%	12%
ACY	ATLANTIC CITY	NJ	21%	18%	15%	8%	3%	0%	0%	0%	1%	5%	13%	17%
EWR	NEWARK	NJ	22%	18%	15%	8%	2%	0%	0%	0%	0%	4%	12%	17%
ABQ	ALBUQUERQUE	NM	23%	17%	11%	6%	2%	0%	0%	0%	0%	5%	14%	22%
CNM	CARLSBAD	NM	25%	18%	10%	4%	1%	0%	0%	0%	0%	4%	14%	23%
CAO	CLAYTON	NM	19%	17%	12%	8%	3%	0%	0%	0%	1%	7%	13%	19%
GUP	GALLUP	NM	18%	15%	12%	9%	5%	0%	0%	0%	2%	8%	13%	18%
ROW	ROSWELL	NM	25%	18%	10%	4%	1%	0%	0%	0%	0%	4%	14%	23%
CVN	TUCUMCARI	NM	22%	17%	12%	7%	2%	0%	0%	0%	1%	6%	13%	20%
ALB	ALBANY	NY	20%	17%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
BGM	BINGHAMTON	NY	19%	16%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%
BUF	BUFFALO	NY	19%	17%	15%	10%	4%	1%	0%	0%	1%	6%	12%	16%
GFL	GLENS FALLS	NY	20%	17%	15%	9%	3%	1%	0%	0%	2%	6%	12%	16%
MSS	MASSENA	NY	19%	17%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%
LGA	NEW YORK	NY	22%	19%	16%	8%	3%	0%	0%	0%	0%	4%	12%	17%
ROC	ROCHESTER	NY	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	12%	16%
SYR	SYRACUSE	NY	19%	17%	15%	9%	3%	1%	0%	0%	2%	6%	12%	16%
UCA	UTICA	NY	23%	20%	15%	7%	1%	0%	0%	0%	0%	4%	12%	18%
ART	WATERTOWN	NY	19%	17%	14%	9%	4%	1%	0%	0%	2%	6%	11%	15%
AVL	ASHEVILLE	NC	22%	17%	13%	7%	2%	0%	0%	0%	1%	6%	15%	18%
HAT	CAPE HATTERAS	NC	31%	24%	17%	2%	0%	0%	0%	0%	0%	0%	8%	17%
CLT	CHARLOTTE	NC	24%	18%	13%	5%	1%	0%	0%	0%	0%	4%	15%	19%
GSO	GREENSBORO	NC	23%	18%	13%	6%	2%	0%	0%	0%	0%	4%	15%	18%
HKY	HICKORY	NC	24%	18%	13%	6%	2%	0%	0%	0%	0%	4%	14%	18%
EWN	NEW BERN	NC	25%	19%	15%	6%	1%	0%	0%	0%	0%	3%	14%	18%
RDU	RALEIGH DURHAM	NC	24%	18%	14%	6%	2%	0%	0%	0%	0%	4%	15%	18%
ILM	WILMINGTON	NC	25%	19%	14%	5%	1%	0%	0%	0%	0%	3%	14%	18%
BIS	BISMARCK	ND	18%	17%	12%	8%	4%	0%	0%	0%	2%	8%	12%	18%
P11	DEVIL'S LAKE	ND	19%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	18%
DIK	DICKINSON	ND	17%	16%	12%	9%	4%	1%	0%	0%	3%	8%	12%	17%
FAR	FARGO	ND	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	18%
GFK	GRAND FORKS	ND	19%	17%	13%	8%	3%	1%	0%	0%	2%	7%	12%	18%
JMS	JAMESTOWN	ND	18%	17%	13%	8%	4%	1%	0%	0%	2%	7%	12%	17%
MOT	MINOT	ND	18%	17%	13%	8%	4%	1%	0%	0%	2%	8%	12%	17%
ISN	WILLISTON	ND	18%	17%	12%	8%	3%	1%	0%	0%	2%	7%	12%	18%
CAK	AKRON CANTON	OH	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
CLE	CLEVELAND	OH	20%	18%	14%	8%	3%	0%	0%	0%	1%	5%	12%	16%
CMH	COLUMBUS	OH	21%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	17%
CVG	CINCINNATI	OH	22%	18%	13%	7%	2%	0%	0%	0%	1%	6%	14%	17%
DAY	DAYTON	OH	21%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	17%
FDY	FINDLAY	OH	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
MFD	MANSFIELD	OH	21%	18%	14%	8%	3%	0%	0%	0%	1%	5%	12%	17%
TOL	TOLEDO	OH	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
YNG	YOUNGSTOWN	OH	20%	17%	14%	8%	3%	1%	0%	0%	2%	6%	12%	16%
LHQ	ZANESVILLE	OH	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
GAG	GAGE	OK	22%	20%	11%	6%	2%	0%	0%	0%	0%	5%	12%	20%
HBR	HOBART	OK	23%	20%	11%	6%	1%	0%	0%	0%	0%	5%	12%	21%
MLC	MCALESTER	OK	24%	20%	11%	5%	1%	0%	0%	0%	0%	5%	13%	20%
OKC	OKLAHOMA CITY	OK	23%	20%	11%	6%	1%	0%	0%	0%	0%	5%	13%	21%
PNC	PONCA CITY	OK	24%	21%	11%	6%	1%	0%	0%	0%	0%	5%	12%	20%
TUL	TULSA	OK	24%	20%	11%	5%	1%	0%	0%	0%	0%	5%	13%	21%
AST	ASTORIA	OR	14%	13%	13%	10%	7%	4%	2%	2%	3%	7%	11%	14%
BKE	BAKER	OR	17%	13%	11%	8%	5%	2%	0%	1%	3%	8%	13%	17%
BNO	BURNS	OR	17%	13%	11%	8%	5%	2%	0%	1%	3%	9%	13%	17%
EUG	EUGENE	OR	17%	14%	13%	9%	5%	2%	0%	0%	2%	8%	13%	17%
MFR	MEDFORD	OR	19%	15%	13%	8%	3%	1%	0%	0%	1%	7%	14%	20%
OTH	NORTH BEND	OR	14%	13%	13%	10%	7%	4%	3%	3%	3%	6%	10%	14%
PDT	PENDLETON	OR	18%	15%	12%	8%	4%	1%	0%	0%	2%	8%	14%	18%
PDX	PORTLAND	OR	18%	15%	13%	8%	4%	1%	0%	0%	1%	7%	13%	18%
RDM	REDMOND	OR	16%	14%	12%	9%	5%	2%	0%	0%	3%	8%	13%	17%
SLE	SALEM	OR	17%	15%	13%	9%	5%	2%	0%	0%	2%	7%	13%	18%
ABE	ALLENTOWN	PA	21%	18%	15%	8%	3%	0%	0%	0%	1%	5%	13%	17%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
AOO	ALTOONA	PA	17%	16%	14%	8%	4%	1%	1%	1%	2%	7%	13%	16%
BFD	BRADFORD	PA	18%	16%	14%	9%	4%	2%	0%	1%	3%	6%	12%	15%
DUJ	DU BOIS	PA	19%	17%	14%	8%	3%	1%	0%	0%	2%	6%	12%	16%
ERI	ERIE	PA	19%	18%	15%	10%	4%	1%	0%	0%	1%	5%	12%	16%
CXY	HARRISBURG	PA	22%	18%	14%	7%	2%	0%	0%	0%	1%	5%	13%	17%
PHL	PHILADELPHIA	PA	22%	19%	15%	7%	2%	0%	0%	0%	0%	4%	13%	17%
PIT	PITTSBURGH	PA	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
AVP	SCRANTON	PA	20%	17%	15%	8%	3%	1%	0%	0%	1%	6%	12%	16%
IPT	WILLIAMSPORT	PA	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
PVD	PROVIDENCE	RI	20%	17%	15%	9%	4%	1%	0%	0%	1%	5%	12%	16%
CHS	CHARLESTON	SC	27%	19%	13%	4%	0%	0%	0%	0%	0%	2%	15%	19%
CAE	COLUMBIA	SC	26%	19%	12%	4%	1%	0%	0%	0%	0%	3%	16%	20%
FLO	FLORENCE	SC	25%	19%	14%	4%	1%	0%	0%	0%	0%	3%	15%	19%
GSP	GREENVILLE	SC	24%	18%	13%	5%	1%	0%	0%	0%	0%	4%	15%	19%
ABR	ABERDEEN	SD	19%	17%	13%	8%	3%	0%	0%	0%	2%	7%	12%	18%
HON	HURON	SD	19%	18%	12%	8%	3%	0%	0%	0%	1%	7%	12%	18%
PIR	PIERRE	SD	19%	18%	13%	8%	4%	0%	0%	0%	1%	7%	12%	18%
RAP	RAPID CITY	SD	17%	17%	12%	9%	5%	1%	0%	0%	2%	8%	12%	17%
FSD	SIOUX FALLS	SD	20%	18%	12%	8%	3%	0%	0%	0%	1%	7%	12%	18%
ATY	WATERTOWN	SD	19%	17%	13%	8%	4%	0%	0%	0%	2%	7%	12%	17%
TRI	BRISTOL	TN	23%	18%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
CHA	CHATTANOOGA	TN	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	15%	20%
CSV	CROSSVILLE	TN	23%	18%	13%	6%	2%	0%	0%	0%	1%	5%	13%	17%
MKL	JACKSON	TN	23%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	19%
TYS	KNOXVILLE	TN	24%	18%	12%	6%	2%	0%	0%	0%	0%	5%	15%	19%
MEM	MEMPHIS	TN	25%	20%	12%	5%	1%	0%	0%	0%	0%	4%	14%	20%
BNA	NASHVILLE	TN	24%	19%	12%	5%	1%	0%	0%	0%	0%	5%	15%	19%
ABI	ABILENE	TX	25%	20%	10%	4%	1%	0%	0%	0%	0%	4%	13%	22%
ALI	ALICE	TX	32%	20%	8%	1%	0%	0%	0%	0%	0%	2%	12%	25%
AMA	AMARILLO	TX	21%	18%	11%	7%	2%	0%	0%	0%	1%	6%	13%	20%
AUS	AUSTIN	TX	29%	20%	10%	3%	0%	0%	0%	0%	0%	3%	13%	23%
BRO	BROWNSVILLE	TX	36%	22%	7%	1%	0%	0%	0%	0%	0%	1%	10%	23%
CLL	COLLEGE STATION	TX	30%	21%	9%	3%	0%	0%	0%	0%	0%	2%	12%	23%
CRP	CORPUS CHRISTI	TX	33%	21%	8%	1%	0%	0%	0%	0%	0%	1%	12%	24%
DHT	DALHART	TX	21%	18%	12%	7%	2%	0%	0%	0%	0%	6%	13%	20%
DFW	DALLAS FT WORTH	TX	27%	21%	10%	4%	1%	0%	0%	0%	0%	3%	13%	23%
DRT	DEL RIO	TX	33%	18%	7%	1%	0%	0%	0%	0%	0%	2%	12%	26%
ELP	EL PASO	TX	29%	18%	8%	2%	0%	0%	0%	0%	0%	2%	13%	27%
GLS	GALVESTON	TX	34%	21%	8%	2%	0%	0%	0%	0%	0%	1%	11%	23%
IAH	HOUSTON	TX	30%	20%	9%	2%	0%	0%	0%	0%	0%	2%	13%	23%
LRD	LAREDO	TX	34%	20%	7%	0%	0%	0%	0%	0%	0%	2%	11%	26%
LBB	LUBBOCK	TX	23%	19%	11%	5%	1%	0%	0%	0%	0%	5%	13%	22%
LFK	LUFKIN	TX	28%	19%	10%	4%	0%	0%	0%	0%	0%	3%	14%	23%
MFE	MCALLEN	TX	34%	21%	6%	1%	0%	0%	0%	0%	0%	2%	12%	25%
MAF	MIDLAND ODESSA	TX	26%	19%	10%	4%	1%	0%	0%	0%	0%	4%	13%	23%
PSX	PALACIOS	TX	32%	20%	9%	2%	0%	0%	0%	0%	0%	2%	12%	23%
CXO	PORT ARTHUR	TX	28%	19%	10%	4%	0%	0%	0%	0%	0%	3%	14%	23%
SJT	SAN ANGELO	TX	27%	20%	10%	3%	1%	0%	0%	0%	0%	4%	13%	22%
SAT	SAN ANTONIO	TX	30%	20%	9%	2%	0%	0%	0%	0%	0%	3%	13%	24%
VCT	VICTORIA	TX	30%	21%	9%	2%	0%	0%	0%	0%	0%	2%	12%	23%
ACT	WACO	TX	26%	20%	11%	4%	0%	0%	0%	0%	0%	3%	13%	22%
SPS	WICHITA FALLS	TX	24%	20%	11%	5%	1%	0%	0%	0%	0%	4%	13%	22%
CDC	CEDAR CITY	UT	18%	15%	12%	8%	5%	0%	0%	0%	2%	8%	13%	19%
SLC	SALT LAKE CITY	UT	21%	16%	11%	8%	3%	0%	0%	0%	1%	7%	13%	21%
BTV	BURLINGTON	VT	19%	17%	15%	9%	3%	1%	0%	0%	2%	6%	12%	16%
MPV	MONTPELIER	VT	18%	16%	14%	9%	4%	2%	0%	1%	3%	7%	12%	15%
LYH	LYNCHBURG	VA	22%	18%	13%	6%	2%	0%	0%	0%	1%	5%	14%	18%
ORF	NORFOLK	VA	24%	19%	15%	6%	1%	0%	0%	0%	0%	3%	13%	18%
RIC	RICHMOND	VA	23%	18%	14%	6%	2%	0%	0%	0%	0%	4%	14%	18%
ROA	ROANOKE	VA	23%	18%	13%	6%	2%	0%	0%	0%	1%	5%	14%	18%
BLI	BELLINGHAM	WA	16%	14%	13%	9%	5%	3%	1%	1%	3%	8%	12%	16%
HQM	HOQUIAM	WA	14%	13%	12%	9%	7%	4%	2%	2%	3%	7%	11%	15%
OLM	OLYMPIA	WA	15%	14%	13%	9%	5%	3%	1%	1%	3%	8%	12%	16%
UIL	QUILLAYUTE	WA	13%	12%	12%	9%	7%	5%	3%	2%	4%	8%	11%	14%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
SEA	SEATTLE TACOMA	WA	16%	15%	13%	9%	5%	2%	0%	0%	2%	8%	13%	17%
GEG	SPOKANE	WA	18%	15%	12%	8%	4%	2%	0%	0%	2%	8%	13%	18%
ALW	WALLA WALLA	WA	20%	16%	12%	7%	2%	1%	0%	0%	1%	6%	14%	20%
EAT	WENATCHEE	WA	20%	16%	12%	7%	2%	1%	0%	0%	1%	8%	14%	20%
YKM	YAKIMA	WA	19%	15%	12%	7%	3%	1%	0%	0%	2%	8%	14%	19%
BKW	BECKLEY	WV	21%	17%	14%	7%	3%	0%	0%	0%	1%	6%	14%	17%
CRW	CHARLESTON	WV	22%	18%	13%	7%	2%	0%	0%	0%	1%	6%	14%	17%
EKN	ELKINS	WV	20%	16%	14%	8%	3%	1%	0%	0%	2%	6%	13%	16%
HTS	HUNTINGTON	WV	22%	18%	13%	7%	2%	0%	0%	0%	1%	6%	14%	18%
MRB	MARTINSBURG	WV	21%	17%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
MGW	MORGANTOWN	WV	21%	18%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
PKB	PARKERSBURG	WV	22%	18%	14%	7%	2%	0%	0%	0%	1%	6%	14%	17%
EAU	EAU CLAIRE	WI	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
GRB	GREEN BAY	WI	19%	18%	13%	9%	4%	1%	0%	0%	2%	7%	12%	17%
LSE	LACROSSE	WI	21%	19%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
MSN	MADISON	WI	20%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
MKE	MILWAUKEE	WI	19%	18%	14%	9%	4%	1%	0%	0%	1%	6%	12%	16%
AUW	WAUSAU	WI	19%	17%	13%	9%	3%	1%	0%	0%	2%	7%	12%	17%
CPR	CASPER	WY	17%	16%	12%	9%	6%	1%	0%	0%	2%	8%	12%	17%
CYS	CHEYENNE	WY	16%	16%	12%	10%	6%	1%	0%	0%	2%	8%	12%	16%
COD	CODY	WY	16%	16%	12%	9%	6%	1%	0%	1%	3%	8%	12%	17%
LND	LANDER	WY	18%	16%	11%	9%	5%	1%	0%	0%	2%	8%	12%	18%
RKS	ROCK SPRINGS	WY	17%	15%	12%	9%	5%	1%	0%	0%	3%	8%	12%	17%
SHR	SHERIDAN	WY	17%	16%	12%	9%	5%	1%	0%	0%	2%	8%	12%	17%
WRL	WORLAND	WY	19%	16%	11%	8%	4%	1%	0%	0%	2%	8%	13%	19%

Table 7C.3.5 Weather Station Monthly Cooling Degree Day Data Fractions (10-Year Average, 2012-2021)

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BHM	BIRMINGHAM	AL	0%	0%	2%	3%	11%	18%	22%	21%	16%	6%	1%	0%
HSV	HUNTSVILLE	AL	0%	0%	1%	3%	11%	19%	23%	21%	15%	5%	1%	0%
MOB	MOBILE	AL	0%	1%	3%	4%	11%	17%	19%	19%	16%	8%	1%	1%
MGM	MONTGOMERY	AL	0%	1%	2%	4%	11%	17%	21%	20%	16%	7%	1%	1%
MSL	MUSCLE SHOALS	AL	0%	0%	1%	3%	10%	20%	24%	22%	15%	5%	1%	0%
TCL	TUSCALOOSA	AL	0%	1%	2%	3%	11%	18%	22%	21%	16%	6%	1%	1%
ANC	ANCHORAGE	AK	0%	0%	0%	0%	0%	19%	60%	21%	0%	0%	0%	0%
BRW	BARROW	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
BET	BETHEL	AK	0%	0%	0%	0%	0%	27%	66%	6%	0%	0%	0%	0%
BTT	BETTLES	AK	0%	0%	0%	0%	2%	41%	50%	7%	0%	0%	0%	0%
BIG	BIG DELTA	AK	0%	0%	0%	0%	2%	36%	48%	13%	0%	1%	0%	0%
CDB	COLD BAY	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
CDV	CORDOVA	AK	0%	0%	0%	0%	0%	75%	13%	13%	0%	0%	0%	0%
FAI	FAIRBANKS	AK	0%	0%	0%	0%	3%	40%	46%	12%	0%	0%	0%	0%
GKN	GULKANA	AK	0%	0%	0%	0%	0%	39%	57%	3%	0%	0%	0%	0%
HOM	HOMER	AK	0%	0%	0%	0%	0%	60%	40%	0%	0%	0%	0%	0%
JNU	JUNEAU	AK	0%	0%	0%	0%	0%	37%	50%	13%	0%	0%	0%	0%
ENA	KENAI	AK	0%	0%	0%	0%	0%	21%	29%	50%	0%	0%	0%	0%
KTN	KETCHIKAN	AK	0%	0%	0%	0%	0%	22%	54%	23%	1%	0%	0%	0%
AKN	KING SALMON	AK	0%	0%	0%	0%	0%	5%	89%	7%	0%	0%	0%	0%
ADQ	KODIAK	AK	0%	0%	0%	0%	2%	7%	41%	50%	0%	0%	0%	0%
OTZ	KOTZEBUE	AK	0%	0%	0%	0%	0%	27%	58%	15%	0%	0%	0%	0%
MCG	MCGRATH	AK	0%	0%	0%	0%	2%	40%	48%	10%	0%	0%	0%	0%
OME	NOME	AK	0%	0%	0%	0%	0%	48%	45%	8%	0%	0%	0%	0%
ORT	NORTHWAY	AK	0%	0%	0%	0%	0%	44%	48%	9%	0%	0%	0%	0%
SNP	ST PAUL ISLAND	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
SIT	SITKA	AK	0%	0%	0%	0%	0%	14%	77%	9%	0%	0%	0%	0%
TKA	TALKEETNA	AK	0%	0%	0%	0%	0%	35%	58%	7%	0%	0%	0%	0%
UNK	UNALAKLEET	AK	0%	0%	0%	0%	13%	20%	42%	24%	0%	0%	0%	0%
VWS	VALDEZ	AK	0%	0%	0%	0%	2%	23%	49%	25%	0%	0%	0%	0%
YAK	YAKUTAT	AK	0%	0%	0%	0%	0%	20%	13%	67%	0%	0%	0%	0%
DUG	DOUGLAS	AZ	0%	0%	1%	5%	10%	21%	21%	19%	14%	6%	2%	0%
FLG	FLAGSTAFF	AZ	0%	0%	0%	2%	7%	22%	31%	24%	12%	3%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
PHX	PHOENIX	AZ	0%	1%	3%	6%	11%	17%	19%	18%	15%	8%	2%	0%
TUS	TUCSON	AZ	0%	0%	2%	5%	10%	19%	20%	19%	15%	8%	2%	0%
INW	WINSLOW	AZ	0%	0%	0%	1%	4%	23%	32%	27%	12%	1%	0%	0%
NYL	YUMA	AZ	0%	1%	3%	6%	10%	16%	19%	19%	15%	9%	3%	0%
ELD	EL DORADO	AR	0%	0%	1%	3%	10%	19%	23%	22%	16%	5%	1%	0%
FYV	FAYETTEVILLE	AR	0%	0%	0%	2%	8%	20%	27%	24%	15%	3%	0%	0%
FSM	FORT SMITH	AR	0%	0%	1%	2%	9%	20%	25%	23%	16%	4%	0%	0%
HRO	HARRISON	AR	0%	0%	1%	2%	8%	18%	26%	23%	15%	5%	1%	0%
LIT	LITTLE ROCK	AR	0%	0%	2%	3%	10%	19%	24%	22%	16%	4%	0%	0%
TXK	TEXARKANA	AR	0%	0%	1%	3%	10%	19%	22%	22%	16%	6%	1%	0%
BFL	BAKERSFIELD	CA	0%	0%	1%	4%	9%	18%	24%	23%	16%	5%	0%	0%
BLH	BLYTHE	CA	0%	0%	2%	6%	10%	16%	20%	20%	15%	8%	1%	0%
EKA	EUREKA	CA	0%	0%	0%	0%	2%	6%	3%	14%	40%	33%	2%	0%
FAT	FRESNO	CA	0%	0%	1%	3%	9%	18%	25%	23%	16%	5%	0%	0%
IPL	IMPERIAL	CA	0%	1%	2%	6%	10%	16%	20%	20%	15%	8%	2%	0%
LAX	LOS ANGELES	CA	1%	1%	1%	2%	3%	7%	18%	22%	22%	16%	5%	1%
MHS	MT SHASTA	CA	0%	0%	0%	1%	6%	17%	31%	27%	13%	4%	0%	0%
PRB	PASO ROBLES	CA	0%	0%	0%	1%	6%	17%	26%	26%	18%	5%	0%	0%
RBL	RED BLUFF	CA	0%	0%	0%	2%	8%	20%	26%	23%	15%	5%	0%	0%
RDD	REDDING	CA	0%	0%	0%	2%	8%	20%	27%	23%	15%	4%	0%	0%
SAC	SACRAMENTO	CA	0%	0%	1%	4%	10%	20%	23%	22%	16%	4%	0%	0%
SAN	SAN DIEGO	CA	0%	1%	1%	3%	4%	8%	19%	24%	23%	14%	3%	0%
SFO	SAN FRANCISCO	CA	0%	0%	1%	3%	5%	13%	13%	19%	28%	19%	1%	0%
SCK	STOCKTON	CA	0%	0%	0%	2%	7%	19%	26%	24%	17%	5%	0%	0%
AKO	AKRON	CO	0%	0%	0%	0%	2%	21%	34%	28%	14%	1%	0%	0%
ALS	ALAMOSA	CO	0%	0%	0%	0%	0%	20%	56%	16%	7%	0%	0%	0%
COS	COLORADO SPRINGS	CO	0%	0%	0%	0%	2%	22%	34%	27%	13%	0%	0%	0%
DEN	DENVER	CO	0%	0%	0%	0%	2%	20%	35%	29%	14%	1%	0%	0%
EGE	EAGLE	CO	0%	0%	0%	0%	1%	20%	50%	24%	5%	1%	0%	0%
GJT	GRAND JUNCTION	CO	0%	0%	0%	0%	4%	23%	34%	27%	11%	0%	0%	0%
LHX	LA JUNTA	CO	0%	0%	0%	1%	5%	23%	31%	25%	14%	1%	0%	0%
PUB	PUEBLO	CO	0%	0%	0%	0%	4%	22%	33%	27%	13%	1%	0%	0%
TAD	TRINIDAD	CO	0%	0%	0%	0%	3%	22%	34%	27%	13%	1%	0%	0%
BDR	BRIDGEPORT	CT	0%	0%	0%	0%	4%	16%	34%	30%	13%	2%	0%	0%
BDL	HARTFORD	CT	0%	0%	0%	0%	6%	17%	36%	28%	11%	1%	0%	0%
ILG	WILMINGTON	DE	0%	0%	0%	1%	7%	18%	30%	25%	14%	4%	0%	0%
DCA	WASHINGTON	DC	0%	0%	0%	2%	9%	19%	28%	24%	14%	4%	0%	0%
DAB	DAYTONA BEACH	FL	1%	2%	4%	6%	10%	13%	15%	16%	14%	10%	5%	3%
FLL	FT LAUDERDALE	FL	4%	5%	6%	8%	9%	11%	12%	12%	11%	10%	7%	6%
FMY	FORT MYERS	FL	2%	4%	5%	8%	11%	12%	13%	13%	12%	10%	5%	4%
GNV	GAINESVILLE	FL	1%	2%	4%	6%	10%	14%	17%	17%	14%	9%	4%	3%
JAX	JACKSONVILLE	FL	1%	1%	3%	5%	10%	16%	18%	18%	15%	8%	2%	2%
EYW	KEY WEST	FL	4%	5%	6%	8%	9%	11%	12%	12%	11%	10%	7%	6%
MLB	MELBOURNE	FL	2%	3%	4%	7%	10%	13%	14%	15%	13%	11%	5%	4%
MIA	MIAMI	FL	4%	5%	6%	8%	10%	11%	12%	12%	11%	10%	6%	5%
MCO	ORLANDO	FL	1%	3%	4%	7%	10%	13%	15%	15%	13%	10%	4%	3%
PNS	PENSACOLA	FL	1%	1%	3%	5%	11%	16%	19%	18%	15%	8%	2%	1%
TLH	TALLAHASSEE	FL	1%	1%	3%	5%	11%	16%	18%	18%	15%	8%	2%	1%
TPA	TAMPA	FL	2%	3%	4%	7%	11%	13%	14%	14%	13%	10%	5%	3%
VRB	VERO BEACH	FL	2%	4%	5%	7%	10%	12%	14%	14%	12%	10%	6%	5%
PBI	WEST PALM BEACH	FL	3%	4%	5%	8%	10%	11%	13%	13%	12%	10%	6%	5%
ABY	ALBANY	GA	1%	2%	4%	6%	11%	15%	17%	16%	14%	9%	3%	2%
AHN	ATHENS	GA	0%	0%	1%	3%	10%	19%	24%	22%	15%	5%	0%	0%
ATL	ATLANTA	GA	0%	0%	1%	3%	11%	18%	23%	22%	16%	5%	0%	0%
AGS	AUGUSTA	GA	0%	0%	1%	3%	10%	18%	23%	21%	15%	6%	1%	0%
BQK	BRUNSWICK	GA	1%	1%	2%	4%	11%	17%	20%	19%	15%	8%	2%	1%
CSG	COLUMBUS	GA	0%	1%	2%	4%	11%	18%	21%	20%	16%	7%	1%	0%
MCN	MACON	GA	0%	0%	1%	3%	11%	18%	23%	21%	15%	6%	1%	0%
SAV	SAVANNAH	GA	0%	1%	2%	5%	11%	17%	20%	19%	15%	7%	2%	1%
AYS	WAYCROSS	GA	1%	1%	3%	6%	11%	16%	19%	18%	14%	7%	2%	1%
ITO	HILO-HAWAII	HI	7%	6%	6%	7%	8%	9%	10%	11%	11%	10%	8%	7%
HNL	HONOLULU-OAHU	HI	6%	6%	6%	7%	8%	9%	11%	11%	10%	10%	8%	7%
OGG	KAHULUI-MAUI	HI	6%	5%	6%	7%	8%	10%	11%	11%	11%	10%	8%	7%
LIH	LIHUE-KAUAI	HI	6%	5%	6%	7%	8%	10%	11%	12%	11%	10%	8%	7%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BOI	BOISE	ID	0%	0%	0%	0%	3%	16%	38%	31%	10%	0%	0%	0%
BYI	BURLEY	ID	0%	0%	0%	0%	1%	16%	45%	30%	7%	1%	0%	0%
IDA	IDAHO FALLS	ID	0%	0%	0%	0%	1%	14%	48%	31%	6%	1%	0%	0%
LWS	LEWISTON	ID	0%	0%	0%	0%	4%	15%	37%	34%	10%	0%	0%	0%
PIH	POCATELLO	ID	0%	0%	0%	0%	1%	15%	45%	32%	7%	0%	0%	0%
ORD	CHICAGO	IL	0%	0%	0%	1%	7%	20%	31%	27%	13%	2%	0%	0%
MLI	MOLINE	IL	0%	0%	0%	1%	8%	23%	30%	23%	13%	2%	0%	0%
PIA	PEORIA	IL	0%	0%	0%	1%	9%	22%	28%	24%	14%	2%	0%	0%
UIN	QUINCY	IL	0%	0%	0%	1%	8%	21%	27%	23%	15%	4%	0%	0%
RFD	ROCKFORD	IL	0%	0%	0%	0%	7%	22%	31%	24%	12%	2%	0%	0%
SPI	SPRINGFIELD	IL	0%	0%	0%	1%	10%	22%	27%	22%	14%	3%	0%	0%
EVV	EVANSVILLE	IN	0%	0%	0%	2%	10%	21%	26%	23%	14%	4%	0%	0%
FWA	FORT WAYNE	IN	0%	0%	0%	0%	9%	23%	31%	23%	12%	2%	0%	0%
IND	INDIANAPOLIS	IN	0%	0%	0%	1%	9%	20%	28%	25%	14%	3%	0%	0%
SBN	SOUTH BEND	IN	0%	0%	0%	0%	8%	21%	30%	25%	13%	2%	0%	0%
LAF	WEST LAFAYETTE	IN	0%	0%	1%	1%	9%	23%	28%	23%	13%	3%	0%	0%
BRL	BURLINGTON	IA	0%	0%	0%	1%	8%	21%	27%	22%	15%	4%	1%	0%
CID	CEDAR RAPIDS	IA	0%	0%	0%	1%	7%	24%	31%	23%	13%	2%	0%	0%
DSM	DES MOINES	IA	0%	0%	0%	1%	7%	23%	30%	24%	13%	1%	0%	0%
DBQ	DUBUQUE	IA	0%	0%	0%	0%	7%	23%	33%	24%	12%	1%	0%	0%
MCW	MASON CITY	IA	0%	0%	0%	0%	7%	26%	33%	22%	12%	1%	0%	0%
OTM	OTTUMWA	IA	0%	0%	0%	1%	7%	23%	30%	23%	13%	2%	0%	0%
SUX	SIOUX CITY	IA	0%	0%	0%	1%	6%	25%	32%	23%	12%	0%	0%	0%
SPW	SPENCER	IA	0%	0%	0%	1%	7%	24%	30%	22%	14%	2%	0%	0%
ALO	WATERLOO	IA	0%	0%	0%	0%	7%	24%	32%	23%	12%	1%	0%	0%
CNU	CHANUTE	KS	0%	0%	0%	2%	8%	21%	28%	24%	14%	3%	0%	0%
CNK	CONCORDIA	KS	0%	0%	0%	1%	7%	24%	29%	23%	15%	2%	0%	0%
DDC	DODGE CITY	KS	0%	0%	0%	1%	6%	22%	28%	24%	15%	2%	0%	0%
GCK	GARDEN CITY	KS	0%	0%	0%	1%	6%	23%	29%	24%	15%	2%	0%	0%
GLD	GOODLAND	KS	0%	0%	0%	0%	4%	22%	32%	26%	14%	1%	0%	0%
RSL	RUSSELL	KS	0%	0%	0%	1%	6%	23%	29%	24%	15%	2%	0%	0%
SLN	SALINA	KS	0%	0%	0%	1%	7%	23%	28%	23%	14%	2%	0%	0%
TOP	TOPEKA	KS	0%	0%	0%	1%	8%	23%	28%	23%	14%	2%	0%	0%
ICT	WICHITA	KS	0%	0%	0%	1%	8%	22%	27%	23%	15%	3%	0%	0%
BWG	BOWLING GREEN	KY	0%	0%	1%	2%	10%	20%	26%	23%	14%	4%	0%	0%
JKL	JACKSON	KY	0%	0%	1%	3%	10%	18%	25%	22%	15%	5%	1%	0%
LEX	LEXINGTON	KY	0%	0%	0%	2%	10%	20%	27%	24%	14%	4%	0%	0%
SDF	LOUISVILLE	KY	0%	0%	1%	2%	11%	20%	25%	23%	14%	4%	0%	0%
PAH	PADUCAH	KY	0%	0%	0%	2%	10%	21%	26%	23%	14%	4%	0%	0%
BTR	BATON ROUGE	LA	1%	1%	4%	5%	11%	15%	18%	18%	15%	8%	2%	2%
LFT	LAFAYETTE	LA	1%	1%	3%	5%	11%	16%	18%	18%	15%	8%	2%	1%
LCH	LAKE CHARLES	LA	1%	1%	3%	5%	11%	16%	18%	19%	15%	8%	2%	1%
MLU	MONROE	LA	0%	1%	2%	4%	11%	18%	21%	21%	16%	6%	1%	1%
MSY	NEW ORLEANS	LA	1%	1%	4%	6%	11%	16%	17%	17%	15%	9%	2%	1%
SHV	SHREVEPORT	LA	0%	1%	2%	4%	10%	18%	21%	21%	16%	6%	1%	1%
AUG	AUGUSTA	ME	0%	0%	0%	0%	3%	15%	38%	33%	11%	1%	0%	0%
BGR	BANGOR	ME	0%	0%	0%	0%	4%	17%	34%	30%	13%	1%	0%	0%
CAR	CARIBOU	ME	0%	0%	0%	0%	4%	14%	40%	34%	8%	0%	0%	0%
HUL	HOULTON	ME	0%	0%	0%	0%	4%	15%	40%	33%	8%	0%	0%	0%
PWM	PORTLAND	ME	0%	0%	0%	0%	3%	15%	38%	33%	11%	0%	0%	0%
BWI	BALTIMORE	MD	0%	0%	0%	1%	8%	19%	30%	25%	13%	3%	0%	0%
SBY	SALISBURY	MD	0%	0%	0%	2%	8%	17%	29%	24%	15%	5%	1%	0%
BOS	BOSTON	MA	0%	0%	0%	0%	4%	16%	34%	31%	12%	1%	0%	0%
CHH	CHATHAM	MA	0%	0%	0%	0%	3%	13%	34%	33%	14%	3%	0%	0%
ORH	WORCESTER	MA	0%	0%	0%	1%	5%	16%	35%	28%	13%	2%	0%	0%
APN	ALPENA	MI	0%	0%	0%	0%	5%	17%	37%	29%	10%	1%	0%	0%
DTW	DETROIT	MI	0%	0%	0%	0%	7%	19%	32%	27%	12%	2%	0%	0%
FNT	FLINT	MI	0%	0%	0%	0%	8%	21%	33%	26%	10%	2%	0%	0%
GRR	GRAND RAPIDS	MI	0%	0%	0%	0%	7%	20%	34%	26%	11%	1%	0%	0%
CMX	HANCOCK	MI	0%	0%	0%	0%	4%	15%	42%	29%	10%	1%	0%	0%
HTL	HOUGHTON LAKE	MI	0%	0%	0%	0%	9%	18%	37%	26%	9%	1%	0%	0%
JXN	JACKSON	MI	0%	0%	0%	0%	7%	20%	33%	26%	12%	2%	0%	0%
LAN	LANSING	MI	0%	0%	0%	0%	7%	20%	34%	27%	11%	1%	0%	0%
SAW	MARQUETTE	MI	0%	0%	0%	0%	5%	18%	43%	25%	9%	0%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MKG	MUSKEGON	MI	0%	0%	0%	0%	6%	18%	34%	28%	12%	1%	0%	0%
MBS	SAGINAW	MI	0%	0%	0%	0%	8%	20%	34%	26%	10%	2%	0%	0%
ANJ	SAULT ST MARIE	MI	0%	0%	0%	0%	4%	13%	41%	32%	10%	0%	0%	0%
TVC	TRAVERSE CITY	MI	0%	0%	0%	0%	6%	17%	34%	29%	12%	1%	0%	0%
AXN	ALEXANDRIA	MN	0%	0%	0%	0%	5%	22%	38%	25%	9%	0%	0%	0%
DLH	DULUTH	MN	0%	0%	0%	0%	3%	15%	45%	30%	7%	0%	0%	0%
HIB	HIBBING	MN	0%	0%	0%	0%	5%	17%	45%	27%	7%	0%	0%	0%
INL	INT'L FALLS	MN	0%	0%	0%	0%	5%	18%	44%	26%	7%	0%	0%	0%
MSP	MINNEAPOLIS	MN	0%	0%	0%	0%	6%	22%	34%	25%	11%	0%	0%	0%
RST	ROCHESTER	MN	0%	0%	0%	0%	7%	25%	34%	22%	11%	0%	0%	0%
STC	SAINT CLOUD	MN	0%	0%	0%	0%	5%	23%	38%	24%	10%	0%	0%	0%
GWO	GREENWOOD	MS	0%	1%	2%	4%	10%	17%	20%	20%	16%	8%	2%	1%
JAN	JACKSON	MS	0%	1%	2%	3%	10%	18%	21%	21%	16%	6%	1%	1%
MCB	MCCOMB	MS	0%	1%	3%	4%	10%	17%	20%	20%	16%	7%	1%	1%
MEI	MERIDIAN	MS	0%	1%	2%	3%	10%	18%	22%	21%	16%	6%	1%	1%
TUP	TUPELO	MS	0%	0%	1%	3%	10%	19%	23%	22%	15%	5%	1%	0%
COU	COLUMBIA	MO	0%	0%	0%	2%	9%	21%	27%	24%	14%	3%	0%	0%
JLN	JOPLIN	MO	0%	0%	1%	2%	8%	20%	27%	24%	14%	4%	0%	0%
MCI	KANSAS CITY	MO	0%	0%	0%	1%	7%	23%	29%	24%	14%	2%	0%	0%
STL	SAINT LOUIS	MO	0%	0%	1%	2%	10%	21%	26%	23%	14%	4%	0%	0%
SGF	SPRINGFIELD	MO	0%	0%	0%	1%	8%	20%	28%	24%	15%	3%	0%	0%
BIL	BILLINGS	MT	0%	0%	0%	0%	2%	16%	40%	31%	10%	0%	0%	0%
BTM	BUTTE	MT	0%	0%	0%	0%	1%	14%	40%	30%	12%	3%	0%	0%
CTB	CUT BANK	MT	0%	0%	0%	1%	1%	11%	39%	34%	11%	3%	0%	0%
GGW	GLASGOW	MT	0%	0%	0%	0%	3%	15%	42%	34%	7%	0%	0%	0%
GTF	GREAT FALLS	MT	0%	0%	0%	0%	1%	10%	45%	35%	8%	0%	0%	0%
HVR	HAVRE	MT	0%	0%	0%	0%	2%	13%	46%	34%	5%	0%	0%	0%
HLN	HELENA	MT	0%	0%	0%	0%	1%	14%	45%	33%	7%	0%	0%	0%
FCA	KALISPELL	MT	0%	0%	0%	1%	6%	19%	40%	27%	6%	1%	0%	0%
LWT	LEWISTOWN	MT	0%	0%	0%	0%	0%	10%	47%	35%	7%	1%	0%	0%
MLS	MILES CITY	MT	0%	0%	0%	0%	2%	16%	42%	31%	9%	0%	0%	0%
MSO	MISSOULA	MT	0%	0%	0%	0%	1%	13%	47%	34%	5%	0%	0%	0%
GRI	GRAND ISLAND	NE	0%	0%	0%	1%	6%	25%	31%	24%	13%	1%	0%	0%
LNK	LINCOLN	NE	0%	0%	0%	1%	7%	24%	30%	24%	13%	1%	0%	0%
OFK	NORFOLK	NE	0%	0%	0%	1%	6%	24%	32%	24%	13%	1%	0%	0%
LBF	NORTH PLATTE	NE	0%	0%	0%	0%	3%	23%	35%	26%	13%	0%	0%	0%
OMA	OMAHA	NE	0%	0%	0%	1%	7%	24%	30%	24%	13%	1%	0%	0%
BFF	SCOTTSBLUFF	NE	0%	0%	0%	0%	2%	22%	37%	28%	11%	0%	0%	0%
VTN	VALENTINE	NE	0%	0%	0%	0%	3%	21%	36%	27%	12%	0%	0%	0%
EKO	ELKO	NV	0%	0%	0%	0%	1%	16%	45%	31%	7%	0%	0%	0%
ELY	ELY	NV	0%	0%	0%	0%	1%	19%	46%	29%	6%	0%	0%	0%
LAS	LAS VEGAS	NV	0%	0%	1%	5%	10%	19%	23%	21%	15%	6%	1%	0%
LOL	LOVELOCK	NV	0%	0%	0%	2%	6%	18%	33%	26%	12%	3%	0%	0%
RNO	RENO	NV	0%	0%	0%	0%	3%	19%	35%	30%	12%	1%	0%	0%
TPH	TONOPAH	NV	0%	0%	0%	0%	4%	20%	35%	29%	10%	1%	0%	0%
WMC	WINNEMUCCA	NV	0%	0%	0%	0%	3%	18%	42%	29%	7%	0%	0%	0%
CON	CONCORD	NH	0%	0%	0%	0%	5%	16%	40%	28%	10%	0%	0%	0%
LEB	LEBANON	NH	0%	0%	0%	0%	7%	18%	33%	27%	13%	3%	0%	0%
MWN	MT WASHINGTON	NH	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
ACY	ATLANTIC CITY	NJ	0%	0%	0%	1%	6%	18%	32%	27%	13%	3%	0%	0%
EWR	NEWARK	NJ	0%	0%	0%	1%	6%	18%	32%	27%	13%	3%	0%	0%
ABQ	ALBUQUERQUE	NM	0%	0%	0%	1%	6%	25%	28%	25%	14%	1%	0%	0%
CNM	CARLSBAD	NM	0%	0%	1%	3%	11%	22%	24%	22%	13%	4%	0%	0%
CAO	CLAYTON	NM	0%	0%	0%	1%	5%	23%	31%	25%	14%	2%	0%	0%
GUP	GALLUP	NM	0%	0%	0%	0%	1%	21%	41%	30%	7%	0%	0%	0%
ROW	ROSWELL	NM	0%	0%	0%	3%	10%	22%	25%	23%	13%	3%	0%	0%
CVN	TUCUMCARI	NM	0%	0%	0%	1%	8%	24%	27%	25%	13%	2%	0%	0%
ALB	ALBANY	NY	0%	0%	0%	0%	7%	18%	36%	27%	11%	1%	0%	0%
BGM	BINGHAMTON	NY	0%	0%	0%	0%	7%	16%	37%	26%	12%	1%	0%	0%
BUF	BUFFALO	NY	0%	0%	0%	0%	7%	16%	34%	29%	12%	2%	0%	0%
GFL	GLENS FALLS	NY	0%	0%	0%	0%	6%	17%	36%	26%	12%	2%	0%	0%
MSS	MASSENA	NY	0%	0%	0%	0%	6%	17%	38%	30%	9%	0%	0%	0%
LGA	NEW YORK	NY	0%	0%	0%	0%	6%	18%	31%	28%	14%	3%	0%	0%
ROC	ROCHESTER	NY	0%	0%	0%	0%	8%	18%	34%	27%	12%	2%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
SYR	SYRACUSE	NY	0%	0%	0%	0%	7%	17%	35%	28%	11%	1%	0%	0%
UCA	UTICA	NY	0%	0%	0%	1%	11%	19%	27%	24%	13%	3%	0%	0%
ART	WATERTOWN	NY	0%	0%	0%	0%	6%	16%	36%	30%	10%	2%	0%	0%
AVL	ASHEVILLE	NC	0%	0%	0%	1%	8%	20%	29%	24%	14%	3%	0%	0%
HAT	CAPE HATTERAS	NC	1%	1%	3%	6%	11%	15%	18%	17%	14%	10%	3%	2%
CLT	CHARLOTTE	NC	0%	0%	1%	3%	10%	19%	26%	23%	14%	4%	0%	0%
GSO	GREENSBORO	NC	0%	0%	1%	2%	10%	20%	27%	23%	14%	3%	0%	0%
HKY	HICKORY	NC	0%	0%	1%	2%	9%	18%	26%	22%	15%	5%	1%	0%
EWN	NEW BERN	NC	0%	0%	1%	3%	10%	18%	24%	22%	15%	6%	1%	1%
RDU	RALEIGH DURHAM	NC	0%	0%	1%	3%	10%	19%	26%	23%	14%	4%	0%	0%
ILM	WILMINGTON	NC	0%	0%	1%	3%	10%	18%	23%	21%	15%	6%	1%	1%
BIS	BISMARCK	ND	0%	0%	0%	0%	4%	20%	41%	27%	8%	0%	0%	0%
P11	DEVIL'S LAKE	ND	0%	0%	0%	0%	7%	22%	33%	26%	11%	1%	0%	0%
DIK	DICKINSON	ND	0%	0%	0%	0%	3%	12%	43%	32%	9%	1%	0%	0%
FAR	FARGO	ND	0%	0%	0%	0%	6%	23%	38%	24%	9%	1%	0%	0%
GFK	GRAND FORKS	ND	0%	0%	0%	0%	5%	20%	36%	26%	11%	2%	0%	0%
JMS	JAMESTOWN	ND	0%	0%	0%	0%	4%	23%	42%	23%	7%	0%	0%	0%
MOT	MINOT	ND	0%	0%	0%	0%	4%	18%	40%	30%	7%	0%	0%	0%
ISN	WILLISTON	ND	0%	0%	0%	0%	5%	19%	36%	29%	10%	1%	0%	0%
CAK	AKRON CANTON	OH	0%	0%	0%	1%	9%	19%	30%	25%	13%	3%	0%	0%
CLE	CLEVELAND	OH	0%	0%	0%	1%	8%	19%	30%	25%	13%	3%	0%	0%
CMH	COLUMBUS	OH	0%	0%	0%	1%	10%	20%	28%	25%	13%	3%	0%	0%
CVG	CINCINNATI	OH	0%	0%	0%	1%	10%	20%	28%	25%	14%	3%	0%	0%
DAY	DAYTON	OH	0%	0%	0%	1%	10%	21%	28%	24%	13%	3%	0%	0%
FDY	FINDLAY	OH	0%	0%	0%	1%	9%	21%	30%	23%	13%	3%	0%	0%
MFD	MANSFIELD	OH	0%	0%	0%	1%	8%	19%	29%	25%	14%	4%	0%	0%
TOL	TOLEDO	OH	0%	0%	0%	0%	8%	20%	31%	25%	12%	2%	0%	0%
YNG	YOUNGSTOWN	OH	0%	0%	0%	1%	9%	19%	32%	25%	12%	3%	0%	0%
LHQ	ZANESVILLE	OH	0%	0%	0%	1%	10%	21%	29%	24%	12%	3%	0%	0%
GAG	GAGE	OK	0%	0%	1%	2%	8%	19%	25%	23%	16%	5%	1%	0%
HBR	HOBART	OK	0%	0%	1%	2%	9%	20%	25%	24%	15%	4%	0%	0%
MLC	MCALESTER	OK	0%	0%	1%	3%	8%	19%	24%	23%	16%	5%	1%	0%
OKC	OKLAHOMA CITY	OK	0%	0%	1%	2%	8%	19%	26%	24%	16%	4%	0%	0%
PNC	PONCA CITY	OK	0%	0%	2%	4%	9%	18%	22%	21%	16%	7%	1%	0%
TUL	TULSA	OK	0%	0%	1%	2%	9%	20%	25%	23%	15%	4%	0%	0%
AST	ASTORIA	OR	0%	0%	0%	3%	4%	16%	13%	37%	27%	0%	0%	0%
BKE	BAKER	OR	0%	0%	0%	0%	2%	12%	44%	35%	7%	0%	0%	0%
BNO	BURNS	OR	0%	0%	0%	0%	1%	14%	47%	32%	6%	0%	0%	0%
EUG	EUGENE	OR	0%	0%	0%	0%	1%	13%	34%	40%	11%	1%	0%	0%
MFR	MEDFORD	OR	0%	0%	0%	1%	4%	16%	34%	31%	13%	1%	0%	0%
OTH	NORTH BEND	OR	0%	0%	0%	3%	7%	16%	23%	25%	18%	7%	1%	0%
PDT	PENDLETON	OR	0%	0%	0%	0%	3%	15%	39%	34%	8%	0%	0%	0%
PDX	PORTLAND	OR	0%	0%	0%	1%	4%	15%	31%	36%	13%	1%	0%	0%
RDM	REDMOND	OR	0%	0%	0%	0%	2%	15%	37%	32%	12%	2%	0%	0%
SLE	SALEM	OR	0%	0%	0%	0%	3%	14%	34%	37%	11%	0%	0%	0%
ABE	ALLENTOWN	PA	0%	0%	0%	1%	7%	18%	34%	26%	12%	2%	0%	0%
AOO	ALTOONA	PA	0%	0%	0%	1%	9%	18%	32%	26%	12%	3%	0%	0%
BFD	BRADFORD	PA	0%	0%	0%	0%	9%	16%	37%	25%	11%	2%	0%	0%
DUJ	DU BOIS	PA	0%	0%	0%	0%	8%	17%	34%	26%	11%	2%	0%	0%
ERI	ERIE	PA	0%	0%	0%	0%	8%	18%	30%	27%	13%	3%	0%	0%
CXY	HARRISBURG	PA	0%	0%	0%	1%	8%	18%	32%	26%	13%	3%	0%	0%
PHL	PHILADELPHIA	PA	0%	0%	0%	1%	7%	19%	31%	26%	14%	3%	0%	0%
PIT	PITTSBURGH	PA	0%	0%	0%	1%	9%	19%	31%	25%	13%	3%	0%	0%
AVP	SCRANTON	PA	0%	0%	0%	1%	8%	17%	34%	26%	12%	2%	0%	0%
IPT	WILLIAMSPORT	PA	0%	0%	0%	0%	7%	17%	34%	27%	12%	2%	0%	0%
PVD	PROVIDENCE	RI	0%	0%	0%	0%	4%	16%	36%	31%	12%	1%	0%	0%
CHS	CHARLESTON	SC	0%	1%	2%	4%	11%	17%	21%	20%	15%	7%	1%	1%
CAE	COLUMBIA	SC	0%	0%	2%	4%	11%	18%	23%	21%	15%	6%	1%	0%
FLO	FLORENCE	SC	0%	0%	1%	4%	11%	18%	23%	21%	15%	6%	1%	1%
GSP	GREENVILLE	SC	0%	0%	1%	2%	10%	20%	25%	22%	15%	4%	0%	0%
ABR	ABERDEEN	SD	0%	0%	0%	0%	5%	24%	37%	24%	9%	0%	0%	0%
HON	HURON	SD	0%	0%	0%	0%	5%	23%	35%	25%	12%	0%	0%	0%
PIR	PIERRE	SD	0%	0%	0%	1%	4%	17%	35%	27%	14%	2%	0%	0%
RAP	RAPID CITY	SD	0%	0%	0%	0%	2%	17%	41%	29%	11%	1%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
FSD	SIOUX FALLS	SD	0%	0%	0%	0%	5%	24%	34%	25%	11%	0%	0%	0%
ATY	WATERTOWN	SD	0%	0%	0%	0%	4%	23%	38%	24%	10%	0%	0%	0%
TRI	BRISTOL	TN	0%	0%	0%	2%	9%	18%	27%	23%	15%	5%	0%	0%
CHA	CHATTANOOGA	TN	0%	0%	1%	2%	10%	19%	24%	22%	15%	5%	0%	0%
CSV	CROSSVILLE	TN	0%	0%	1%	2%	9%	17%	26%	23%	15%	6%	1%	0%
MKL	JACKSON	TN	0%	0%	1%	2%	10%	19%	25%	22%	14%	6%	1%	0%
TYS	KNOXVILLE	TN	0%	0%	1%	2%	10%	19%	25%	23%	15%	4%	0%	0%
MEM	MEMPHIS	TN	0%	0%	1%	3%	11%	19%	23%	22%	16%	5%	0%	0%
BNA	NASHVILLE	TN	0%	0%	1%	2%	10%	20%	25%	22%	14%	4%	0%	0%
ABI	ABILENE	TX	0%	0%	2%	4%	10%	18%	22%	22%	14%	6%	1%	0%
ALI	ALICE	TX	1%	2%	5%	7%	11%	14%	16%	16%	13%	9%	3%	2%
AMA	AMARILLO	TX	0%	0%	0%	2%	8%	21%	27%	25%	14%	3%	0%	0%
AUS	AUSTIN	TX	0%	1%	3%	5%	10%	17%	20%	20%	15%	7%	2%	1%
BRO	BROWNSVILLE	TX	2%	3%	5%	8%	11%	13%	14%	15%	12%	9%	5%	3%
CLL	COLLEGE STATION	TX	1%	1%	3%	5%	10%	15%	18%	19%	15%	8%	3%	2%
CRP	CORPUS CHRISTI	TX	1%	2%	4%	7%	11%	14%	16%	17%	14%	9%	3%	2%
DHT	DALHART	TX	0%	0%	0%	1%	6%	20%	28%	24%	15%	4%	1%	0%
DFW	DALLAS FT WORTH	TX	0%	0%	2%	4%	10%	18%	22%	22%	16%	6%	1%	0%
DRT	DEL RIO	TX	0%	1%	3%	7%	12%	16%	19%	19%	14%	8%	2%	0%
ELP	EL PASO	TX	0%	0%	1%	5%	12%	22%	22%	20%	13%	5%	0%	0%
GLS	GALVESTON	TX	0%	1%	3%	6%	11%	15%	17%	18%	15%	10%	3%	2%
IAH	HOUSTON	TX	1%	1%	3%	5%	11%	16%	18%	19%	14%	8%	2%	1%
LRD	LAREDO	TX	1%	2%	5%	8%	12%	15%	16%	16%	12%	9%	3%	2%
LBB	LUBBOCK	TX	0%	0%	1%	3%	10%	21%	25%	23%	13%	4%	0%	0%
LFK	LUFKIN	TX	0%	1%	3%	5%	11%	17%	20%	20%	15%	7%	1%	1%
MFE	MCALLEN	TX	2%	3%	6%	8%	11%	13%	14%	15%	12%	9%	4%	3%
MAF	MIDLAND ODESSA	TX	0%	0%	2%	5%	12%	19%	22%	21%	13%	6%	1%	0%
PSX	PALACIOS	TX	1%	1%	3%	6%	11%	16%	17%	18%	14%	8%	3%	2%
CXO	PORT ARTHUR	TX	0%	1%	3%	5%	11%	17%	19%	20%	15%	7%	2%	1%
SJT	SAN ANGELO	TX	0%	0%	2%	5%	11%	18%	21%	21%	14%	6%	1%	0%
SAT	SAN ANTONIO	TX	0%	1%	3%	6%	11%	16%	19%	20%	14%	8%	2%	1%
VCT	VICTORIA	TX	1%	1%	3%	6%	11%	16%	17%	18%	14%	8%	3%	1%
ACT	WACO	TX	0%	0%	2%	4%	10%	18%	21%	22%	15%	7%	1%	1%
SPS	WICHITA FALLS	TX	0%	0%	1%	3%	10%	19%	24%	23%	15%	5%	0%	0%
CDC	CEDAR CITY	UT	0%	0%	0%	0%	2%	21%	38%	30%	9%	0%	0%	0%
SLC	SALT LAKE CITY	UT	0%	0%	0%	0%	4%	20%	35%	29%	12%	1%	0%	0%
BTV	BURLINGTON	VT	0%	0%	0%	0%	7%	17%	35%	29%	11%	1%	0%	0%
MPV	MONTPELIER	VT	0%	0%	0%	0%	5%	17%	39%	29%	9%	1%	0%	0%
LYH	LYNCHBURG	VA	0%	0%	0%	2%	9%	19%	30%	24%	13%	3%	0%	0%
ORF	NORFOLK	VA	0%	0%	1%	3%	9%	18%	26%	23%	15%	5%	0%	0%
RIC	RICHMOND	VA	0%	0%	0%	2%	10%	19%	27%	24%	14%	4%	0%	0%
ROA	ROANOKE	VA	0%	0%	0%	2%	10%	19%	29%	24%	13%	3%	0%	0%
BLI	BELLINGHAM	WA	0%	0%	0%	0%	0%	16%	35%	42%	6%	0%	0%	0%
HQM	HOQUIAM	WA	0%	0%	0%	2%	5%	21%	10%	36%	26%	0%	0%	0%
OLM	OLYMPIA	WA	0%	0%	0%	0%	1%	18%	34%	41%	7%	0%	0%	0%
UIL	QUILLAYUTE	WA	0%	0%	0%	1%	2%	25%	9%	48%	16%	0%	0%	0%
SEA	SEATTLE TACOMA	WA	0%	0%	0%	0%	4%	14%	33%	38%	10%	0%	0%	0%
GEG	SPOKANE	WA	0%	0%	0%	0%	3%	14%	40%	35%	7%	0%	0%	0%
ALW	WALLA WALLA	WA	0%	0%	0%	1%	6%	16%	33%	30%	12%	3%	0%	0%
EAT	WENATCHEE	WA	0%	0%	0%	0%	5%	16%	37%	32%	8%	1%	0%	0%
YKM	YAKIMA	WA	0%	0%	0%	0%	5%	18%	39%	31%	6%	0%	0%	0%
BKW	BECKLEY	WV	0%	0%	0%	1%	9%	18%	31%	25%	13%	2%	0%	0%
CRW	CHARLESTON	WV	0%	0%	0%	2%	10%	18%	28%	24%	14%	3%	0%	0%
EKN	ELKINS	WV	0%	0%	0%	0%	7%	18%	33%	25%	13%	2%	0%	0%
HTS	HUNTINGTON	WV	0%	0%	1%	2%	10%	19%	27%	24%	14%	3%	0%	0%
MRB	MARTINSBURG	WV	0%	0%	0%	1%	8%	19%	31%	25%	12%	3%	0%	0%
MGW	MORGANTOWN	WV	0%	0%	0%	2%	10%	18%	29%	24%	14%	3%	0%	0%
PKB	PARKERSBURG	WV	0%	0%	0%	1%	11%	18%	29%	23%	14%	3%	0%	0%
EAU	EAU CLAIRE	WI	0%	0%	0%	0%	6%	22%	37%	25%	10%	0%	0%	0%
GRB	GREEN BAY	WI	0%	0%	0%	0%	6%	21%	37%	25%	10%	1%	0%	0%
LSE	LACROSSE	WI	0%	0%	0%	0%	7%	22%	33%	25%	11%	1%	0%	0%
MSN	MADISON	WI	0%	0%	0%	0%	7%	22%	35%	25%	10%	1%	0%	0%
MKE	MILWAUKEE	WI	0%	0%	0%	0%	5%	17%	34%	29%	13%	2%	0%	0%
AUW	WAUSAU	WI	0%	0%	0%	0%	6%	21%	38%	25%	10%	0%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
CPR	CASPER	WY	0%	0%	0%	0%	1%	15%	45%	31%	9%	0%	0%	0%
CYS	CHEYENNE	WY	0%	0%	0%	0%	1%	17%	41%	31%	11%	0%	0%	0%
COD	CODY	WY	0%	0%	0%	0%	1%	14%	44%	29%	10%	2%	0%	0%
LND	LANDER	WY	0%	0%	0%	0%	1%	14%	37%	36%	12%	0%	0%	0%
RKS	ROCK SPRINGS	WY	0%	0%	0%	0%	0%	16%	47%	30%	6%	0%	0%	0%
SHR	SHERIDAN	WY	0%	0%	0%	0%	1%	13%	45%	33%	9%	0%	0%	0%
WRL	WORLAND	WY	0%	0%	0%	0%	2%	19%	42%	31%	6%	1%	0%	0%

7C.3.2 Monthly Average Outdoor Temperature Data by Weather Station

Table 7C.3.6 shows for each weather station the 30-year (1991-2020) monthly average outdoor temperature data based on NOAA data.[4]

Table 7C.3.6 Weather Station Monthly Average Outdoor Temperature (1991-2020)

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	44.7	48.8	56.0	63.6	71.5	78.3	81.5	80.9	75.6	64.9	54.0	47.4
HSV	HUNTSVILLE	AL	42.7	46.7	54.2	62.9	71.3	78.6	81.3	80.5	74.9	63.9	52.5	45.5
MOB	MOBILE	AL	51.1	55.0	60.9	66.9	74.4	80.1	82.0	81.9	78.1	69.0	58.9	53.3
MGM	MONTGOMERY	AL	48.1	52.6	59.2	65.7	73.6	80.2	82.9	82.5	77.8	67.4	56.6	50.2
MSL	MUSCLE SHOALS	AL	42.9	46.7	54.4	62.9	71.3	78.4	81.5	80.5	74.7	63.6	52.5	45.6
TCL	TUSCALOOSA	AL	45.7	49.6	56.9	63.8	72.2	79.1	81.9	81.5	76.3	65.2	54.2	48.0
ANC	ANCHORAGE	AK	16.9	21.3	25.8	37.5	48.1	55.9	59.6	57.5	49.3	36.3	23.6	19.4
BRW	BARROW	AK	-11.5	-11.9	-10.5	4.0	22.7	36.0	41.7	39.8	33.7	21.2	5.7	-6.3
BET	BETHEL	AK	6.9	13.3	14.5	29.0	43.0	53.3	56.3	53.9	46.1	32.2	18.5	10.0
BTT	BETTLES	AK	-10.6	-3.4	3.7	24.6	45.0	58.6	59.8	52.7	41.2	21.3	0.3	-6.0
BIG	BIG DELTA	AK	-1.0	7.3	14.2	33.9	48.5	58.5	60.7	55.6	44.8	26.5	8.2	2.4
CDB	COLD BAY	AK	28.4	30.2	29.9	35.0	41.0	47.1	51.5	52.6	48.4	41.3	35.3	30.8
CDV	CORDOVA	AK	26.4	29.1	30.8	38.1	45.5	51.4	54.6	54.1	48.4	40.1	31.6	28.9
FAI	FAIRBANKS	AK	-8.3	0.2	10.7	33.7	50.3	61.0	62.9	57.0	45.8	26.2	4.1	-4.3
GKN	GULKANA	AK	-3.4	5.6	14.7	32.6	45.8	54.9	57.9	53.5	43.6	27.1	6.8	-0.2
HOM	HOMER	AK	25.4	28.3	30.1	38.7	46.0	52.0	56.1	55.3	49.5	40.2	31.2	27.7
JNU	JUNEAU	AK	28.5	30.1	32.9	40.8	49.0	54.6	57.0	56.0	50.1	42.2	33.8	30.3
ENA	KENAI	AK	14.9	19.9	23.6	36.0	45.4	52.1	56.0	54.8	47.8	35.9	23.2	18.1
KTN	KETCHIKAN	AK	35.6	36.2	38.0	43.5	50.1	55.3	58.8	59.0	53.6	46.2	39.7	36.4
AKN	KING SALMON	AK	16.6	22.1	23.5	36.0	45.6	52.8	56.7	55.7	48.7	36.4	25.0	18.6
ADQ	KODIAK	AK	31.2	32.4	33.2	39.1	45.8	51.4	56.2	56.5	50.6	42.2	35.7	31.9
OTZ	KOTZEBUE	AK	-1.9	1.4	1.5	16.3	33.1	47.5	55.3	52.1	43.1	26.9	10.8	2.4
MCG	MCGRATH	AK	-5.8	4.5	11.9	32.2	48.4	58.7	60.8	55.9	46.0	28.4	8.0	-2.3
OME	NOME	AK	5.6	9.0	9.6	22.7	37.3	48.3	52.0	50.2	43.1	30.4	18.2	9.1
ORT	NORTHWAY	AK	-13.3	-4.0	8.3	31.1	47.2	57.2	59.9	55.0	43.2	23.2	-0.7	-10.8
SNP	ST PAUL ISLAND	AK	25.3	25.3	25.1	30.1	36.6	43.1	47.9	49.5	46.0	39.5	33.9	28.9
SIT	SITKA	AK	36.5	36.7	37.5	42.6	48.1	53.0	56.5	57.3	53.2	46.4	40.0	37.5
TKA	TALKEETNA	AK	13.6	18.8	23.5	36.2	47.7	57.0	60.1	56.5	47.5	34.2	20.6	15.6
UNK	UNALAKLEET	AK	-4.0	4.1	9.7	27.6	45.1	57.4	59.3	54.3	44.5	27.8	9.4	0.1
VWS	VALDEZ	AK	23.9	26.7	29.9	39.2	47.7	54.4	56.6	54.5	48.3	39.5	29.4	26.2
YAK	YAKUTAT	AK	28.6	30.6	31.9	38.6	45.6	51.9	55.4	54.7	49.4	41.9	33.7	30.8
DUG	DOUGLAS	AZ	45.1	48.6	54.2	60.5	68.8	77.9	79.3	77.7	73.6	64.0	52.8	44.8
FLG	FLAGSTAFF	AZ	30.5	32.6	38.0	43.7	51.3	60.8	66.7	64.9	58.3	47.6	37.5	30.0
PHX	PHOENIX	AZ	56.8	59.9	66.3	73.2	82.0	91.4	95.5	94.4	89.2	77.4	65.1	55.8
TUS	TUCSON	AZ	53.6	56.2	61.9	68.1	76.8	86.1	88.2	86.9	82.8	72.6	61.5	53.0
INW	WINSLOW	AZ	35.9	41.0	48.2	54.9	63.7	73.8	79.1	77.1	69.7	57.1	44.6	35.2
NYL	YUMA	AZ	55.9	58.6	64.6	70.5	77.7	86.5	93.0	92.5	86.4	74.7	63.0	54.4
ELD	EL DORADO	AR	44.7	48.5	56.3	63.9	72.0	79.3	82.4	81.8	75.8	64.6	53.8	46.8
FYV	FAYETTEVILLE	AR	36.7	40.6	48.5	58.1	66.0	74.8	79.1	78.1	70.6	59.4	48.1	39.7
FSM	FORT SMITH	AR	40.4	45.0	53.5	62.1	70.4	78.8	83.1	82.3	74.8	63.5	51.7	42.8
HRO	HARRISON	AR	37.0	40.9	49.2	58.3	66.2	74.4	78.5	77.6	69.9	59.4	48.5	39.7
LIT	LITTLE ROCK	AR	40.7	44.7	52.7	61.4	69.9	78.0	81.4	80.8	74.0	62.6	51.1	43.0
TXK	TEXARKANA	AR	44.6	48.3	56.0	63.6	71.6	78.9	82.5	82.0	75.4	64.9	53.9	46.4
BFL	BAKERSFIELD	CA	49.5	53.8	58.6	63.3	71.1	78.7	84.8	83.4	78.2	67.7	56.3	49.2

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BLH	BLYTHE	CA	54.8	58.3	64.5	71.7	80.5	88.3	93.9	93.4	87.4	73.8	62.6	52.1
EKA	EUREKA	CA	47.9	48.4	49.2	50.8	53.7	56.0	57.7	58.5	57.2	54.3	50.5	47.4
FAT	FRESNO	CA	48.0	52.3	57.4	62.3	70.2	77.6	83.5	82.2	77.1	66.7	55.1	47.5
IPL	IMPERIAL	CA	56.0	59.4	65.3	70.9	78.2	86.8	93.1	93.6	87.2	75.2	63.3	54.9
LAX	LOS ANGELES	CA	57.9	57.9	59.1	61.1	63.6	66.4	69.6	70.7	70.1	67.1	62.3	57.6
MHS	MT SHASTA	CA	35.8	37.9	41.9	46.5	54.2	61.1	68.1	66.8	61.0	50.9	40.5	34.8
PRB	PASO ROBLES	CA	48.1	50.3	53.9	57.2	62.8	68.3	72.0	72.4	69.3	62.0	53.0	47.0
RBL	RED BLUFF	CA	47.4	50.8	54.7	59.6	68.0	76.4	82.0	79.9	75.4	65.1	53.4	46.8
RDD	REDDING	CA	47.5	50.5	54.4	59.4	68.2	77.1	83.4	81.0	75.3	64.8	52.9	46.6
SAC	SACRAMENTO	CA	47.6	51.4	55.4	59.5	66.1	72.2	75.9	75.3	72.5	64.5	53.9	47.3
SAN	SAN DIEGO	CA	58.4	59.0	60.7	62.9	64.8	67.2	70.7	72.4	71.7	68.1	62.7	57.9
SFO	SAN FRANCISCO	CA	51.3	53.5	55.5	57.3	59.9	62.5	64.0	64.9	65.3	62.9	56.4	51.4
SCK	STOCKTON	CA	48.0	52.1	56.4	60.9	67.7	74.0	78.1	77.3	73.9	65.5	54.7	47.7
AKO	AKRON	CO	29.1	31.3	40.5	47.2	56.9	68.2	74.5	72.5	64.1	50.2	38.3	29.3
ALS	ALAMOSA	CO	16.8	24.3	35.2	42.6	51.7	60.6	65.3	63.2	55.9	43.8	30.3	18.1
COS	COLORADO SPRINGS	CO	31.7	33.4	41.1	47.5	57.1	67.2	72.4	70.1	63.0	50.7	39.5	31.7
DEN	DENVER	CO	31.7	32.7	41.6	47.8	57.4	68.2	75.1	72.9	64.8	51.1	39.4	31.2
EGE	EAGLE	CO	17.5	21.1	29.2	36.6	45.7	53.5	59.2	57.4	50.3	39.7	26.4	17.6
GJT	GRAND JUNCTION	CO	27.7	35.3	45.0	51.9	62.0	73.0	79.2	76.3	67.1	53.2	39.6	28.4
LHX	LA JUNTA	CO	32.3	35.9	45.5	53.2	63.4	74.2	79.1	76.8	68.6	54.6	41.8	32.3
PUB	PUEBLO	CO	31.9	35.1	43.9	51.3	61.4	71.8	77.2	74.8	66.6	52.8	40.5	31.7
TAD	TRINIDAD	CO	35.7	37.9	45.3	51.7	60.8	70.3	74.3	72.2	66.0	54.6	43.4	35.4
BDR	BRIDGEPORT	CT	31.4	33.1	39.9	50.0	60.0	69.6	75.7	74.5	67.6	56.4	46.0	37.0
BDL	HARTFORD	CT	27.1	29.6	37.8	49.5	60.0	68.9	74.3	72.5	64.8	53.0	42.3	32.6
ILG	WILMINGTON	DE	33.5	35.5	43.2	53.9	63.5	72.6	77.6	75.8	68.9	57.2	46.6	38.2
DCA	WASHINGTON	DC	33.9	36.4	44.2	55.0	64.0	72.5	77.2	75.7	68.6	56.6	46.0	37.7
DAB	DAYTONA BEACH	FL	58.8	61.4	65.2	70.2	75.6	80.2	81.9	81.9	80.1	74.4	67.0	61.8
FLL	FT LAUDERDALE	FL	68.3	70.3	72.6	76.4	79.7	82.5	83.8	84.0	82.7	79.9	74.6	71.2
FMY	FORT MYERS	FL	64.7	67.3	70.3	74.8	79.3	82.3	83.2	83.4	82.2	78.0	71.5	67.3
GNV	GAINESVILLE	FL	54.8	58.4	62.7	68.5	75.0	79.9	81.4	81.3	78.8	71.4	62.7	57.3
JAX	JACKSONVILLE	FL	54.9	58.0	62.6	68.3	74.4	79.9	82.2	81.7	78.8	71.9	63.3	57.6
EYW	KEY WEST	FL	70.6	72.3	74.4	77.9	81.1	84.1	85.4	85.5	84.1	81.3	76.6	73.0
MLB	MELBOURNE	FL	63.3	65.4	68.6	73.1	78.1	81.9	83.1	83.4	82.1	77.5	70.7	66.2
MIA	MIAMI	FL	68.6	70.7	73.1	76.7	80.1	82.8	84.1	84.2	83.0	80.1	74.8	71.2
MCO	ORLANDO	FL	60.6	63.6	67.3	72.2	77.3	81.2	82.6	82.6	81.0	75.5	68.2	63.3
PNS	PENSACOLA	FL	53.2	56.8	62.3	68.3	76.0	81.7	83.5	83.0	80.0	71.3	61.4	55.5
TLH	TALLAHASSEE	FL	52.2	55.6	61.4	67.3	75.2	80.8	82.5	82.4	79.1	70.3	60.2	54.4
TPA	TAMPA	FL	61.2	64.0	67.5	72.3	77.2	81.0	82.2	82.4	81.2	75.9	68.5	63.9
VRB	VERO BEACH	FL	62.8	65.0	68.0	72.1	76.7	80.6	81.9	82.1	80.9	76.9	70.4	65.7
PBI	WEST PALM BEACH	FL	66.3	68.4	71.1	74.9	78.7	81.7	83.1	83.2	81.9	78.7	73.0	69.0
ABY	ALBANY	GA	50.5	54.0	60.3	67.0	75.3	80.9	83.1	82.7	78.1	68.9	58.7	52.7
AHN	ATHENS	GA	44.3	47.9	54.9	62.3	70.5	77.7	81.0	79.8	73.9	63.5	53.3	46.5
ATL	ATLANTA	GA	44.8	48.5	55.6	63.2	71.2	77.9	80.9	80.2	74.9	64.7	54.2	47.3
AGS	AUGUSTA	GA	47.4	50.8	57.5	64.6	72.7	79.7	82.8	81.8	76.4	66.0	55.6	49.4
BQK	BRUNSWICK	GA	53.0	56.1	61.7	68.0	75.6	81.0	83.6	82.8	79.1	71.3	62.0	55.7
CSG	COLUMBUS	GA	48.5	52.3	58.9	65.8	74.1	80.4	83.2	82.4	77.6	67.6	57.3	50.6
MCN	MACON	GA	47.6	51.2	57.7	64.5	72.9	79.5	82.5	81.4	76.2	66.0	55.8	49.5
SAV	SAVANNAH	GA	50.7	54.0	60.0	66.7	74.1	80.1	83.0	82.1	77.7	68.8	59.1	53.2
AYS	WAYCROSS	GA	50.3	54.1	59.9	66.2	74.0	80.4	82.7	81.9	77.4	68.1	59.4	53.0
ITO	HILO-HAWAII	HI	71.4	71.2	71.9	72.5	74.0	75.2	76.3	76.6	76.5	75.7	74.0	72.2
HNL	HONOLULU-OAHU	HI	73.6	73.8	74.7	76.6	78.2	80.3	81.6	82.2	81.6	80.4	78.0	75.5
OGG	KAHULUI-MAUI	HI	72.9	73.0	74.0	75.5	77.1	79.3	80.5	81.1	80.6	79.4	77.1	74.6
LIH	LIHUE-KAUAI	HI	72.3	72.2	72.9	74.6	76.3	78.3	79.6	80.2	80.0	78.7	76.2	73.9
BOI	BOISE	ID	32.2	37.5	45.2	50.9	59.9	67.8	77.3	75.8	66.3	53.2	40.3	32.1
BYI	BURLEY	ID	29.2	33.3	41.4	47.1	55.8	63.4	71.5	69.9	60.8	49.1	37.6	29.2
IDA	IDAHO FALLS	ID	20.4	24.9	36.2	44.4	52.8	60.4	68.0	66.5	57.7	45.0	32.4	21.9
LWS	LEWISTON	ID	36.2	39.3	45.4	51.5	60.0	66.5	75.8	75.2	65.9	52.5	41.6	35.2
PIH	POCATELLO	ID	25.6	29.7	39.1	45.7	54.2	62.2	70.8	69.3	59.7	47.1	34.9	25.8
ORD	CHICAGO	IL	25.2	28.8	39.0	49.7	60.6	70.6	75.4	73.8	66.3	54.0	41.3	30.5
MLI	MOLINE	IL	23.3	27.7	39.7	51.4	62.5	72.1	75.5	73.4	66.1	53.7	40.4	28.9
PIA	PEORIA	IL	25.6	30.0	41.4	52.9	63.5	72.8	76.3	74.5	67.4	54.9	41.9	30.9
UIN	QUINCY	IL	26.6	31.2	42.1	53.3	63.6	72.8	76.3	74.5	67.0	55.1	42.3	31.6
RFD	ROCKFORD	IL	21.8	25.6	37.3	49.1	60.4	70.1	73.8	71.9	64.4	52.0	38.8	27.3
SPI	SPRINGFIELD	IL	27.9	32.4	43.2	54.4	65.1	73.7	76.5	74.9	68.0	56.0	43.5	32.9

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
EVV	EVANSVILLE	IN	33.6	37.6	46.6	57.2	66.9	75.5	78.7	77.3	70.3	58.6	46.3	37.5
FWA	FORT WAYNE	IN	25.5	28.7	38.6	50.2	61.3	70.7	73.8	71.6	64.8	53.2	41.1	30.9
IND	INDIANAPOLIS	IN	28.5	32.5	42.4	53.6	63.6	72.5	75.8	74.7	67.8	55.5	43.3	33.3
SBN	SOUTH BEND	IN	24.1	27.1	36.7	48.1	59.1	68.8	72.4	70.7	63.7	52.0	39.8	29.6
LAF	WEST LAFAYETTE	IN	25.8	29.7	40.0	51.1	61.6	70.7	73.6	72.2	65.5	53.7	41.3	31.0
BRL	BURLINGTON	IA	24.3	28.8	40.7	52.3	63.0	72.5	75.6	73.8	66.7	54.2	41.0	29.9
CID	CEDAR RAPIDS	IA	19.6	24.1	36.5	48.9	60.3	69.9	72.8	70.8	63.3	50.7	37.0	25.2
DSM	DES MOINES	IA	22.3	26.9	39.4	51.3	62.4	72.2	76.0	73.9	66.2	53.2	39.3	27.7
DBQ	DUBUQUE	IA	18.8	22.9	35.2	47.4	58.8	68.5	71.7	69.8	62.3	49.9	36.4	24.5
MCW	MASON CITY	IA	15.7	20.0	32.9	46.0	58.2	68.5	71.5	68.9	61.4	48.2	33.9	21.6
OTM	OTTUMWA	IA	22.9	27.4	39.6	51.1	62.0	71.6	75.1	73.0	65.3	52.9	39.6	28.4
SUX	SIOUX CITY	IA	20.0	24.5	36.7	48.9	60.5	70.7	74.2	71.7	63.9	50.3	35.9	24.1
SPW	SPENCER	IA	16.9	21.4	34.2	47.2	59.4	69.8	73.4	70.6	63.0	49.4	34.6	22.2
ALO	WATERLOO	IA	19.4	23.9	36.7	49.4	61.5	71.5	74.5	71.9	64.6	51.6	37.4	25.3
CNU	CHANUTE	KS	33.7	38.3	48.3	57.7	66.9	76.2	80.6	79.6	71.1	59.4	47.1	37.1
CNK	CONCORDIA	KS	28.8	32.8	43.5	53.1	63.5	74.4	78.9	76.4	68.5	55.6	42.1	31.5
DDC	DODGE CITY	KS	33.0	36.2	45.4	54.3	64.8	75.1	80.1	78.1	70.0	56.8	43.7	33.9
GCK	GARDEN CITY	KS	31.2	34.7	44.0	52.7	63.4	73.8	78.4	76.2	68.6	55.1	41.9	32.3
GLD	GOODLAND	KS	30.2	32.3	41.4	49.3	59.6	70.7	76.1	73.6	65.3	51.8	39.6	30.8
RSL	RUSSELL	KS	30.5	33.9	44.1	53.4	63.9	75.1	79.9	77.5	69.2	55.9	42.5	32.1
SLN	SALINA	KS	30.8	34.9	45.3	54.6	65.1	76.2	80.9	78.6	70.1	57.0	43.6	32.9
TOP	TOPEKA	KS	30.2	34.9	45.6	55.5	65.7	75.5	79.8	77.9	69.2	57.0	44.2	33.9
ICT	WICHITA	KS	33.2	37.6	47.4	56.5	66.7	76.9	81.5	79.9	71.7	59.0	45.8	35.6
BWG	BOWLING GREEN	KY	35.7	39.7	48.2	58.4	66.4	73.3	76.4	75.8	69.7	59.1	48.0	39.5
JKL	JACKSON	KY	35.8	39.7	47.8	58.2	65.6	72.6	75.7	74.9	69.1	58.7	48.1	39.7
LEX	LEXINGTON	KY	33.9	37.5	45.9	56.2	65.4	73.3	76.7	75.7	69.1	57.8	46.1	37.8
SDF	LOUISVILLE	KY	35.7	39.5	48.4	59.0	68.3	76.4	79.9	78.9	72.0	60.3	48.5	39.6
PAH	PADUCAH	KY	36.0	40.1	49.0	59.0	68.4	76.5	79.7	78.2	71.0	59.7	48.0	39.5
BTR	BATON ROUGE	LA	52.0	55.9	62.0	68.0	75.5	81.0	82.9	82.8	78.8	69.5	59.4	53.8
LFT	LAFAYETTE	LA	52.8	56.8	62.9	69.2	76.5	81.6	83.3	83.5	79.7	70.7	60.8	54.9
LCH	LAKE CHARLES	LA	53.2	56.9	63.1	69.1	76.4	82.1	83.9	84.0	80.1	71.3	61.4	55.3
MLU	MONROE	LA	46.8	50.7	58.1	65.5	73.8	80.3	82.8	82.5	77.1	66.3	55.6	48.8
MSY	NEW ORLEANS	LA	54.3	58.0	63.8	70.1	77.1	82.4	83.9	84.0	80.8	72.5	62.4	56.6
SHV	SHREVEPORT	LA	47.9	51.8	59.0	65.9	74.0	80.9	83.9	84.0	78.3	67.4	56.6	49.5
AUG	AUGUSTA	ME	20.4	23.2	32.0	43.8	55.3	64.2	70.1	68.9	61.0	49.2	38.0	27.2
BGR	BANGOR	ME	18.5	21.0	30.6	42.8	54.5	63.6	69.5	68.2	59.9	48.2	37.3	25.9
CAR	CARIBOU	ME	11.7	14.2	25.0	38.5	52.2	61.4	66.7	64.9	56.6	44.5	32.6	19.9
HUL	HOULTON	ME	12.9	14.8	25.5	38.6	51.2	60.2	66.1	64.4	56.2	44.3	33.1	20.9
PWM	PORTLAND	ME	24.0	26.2	34.1	44.6	54.9	64.3	70.4	69.2	61.6	50.3	40.0	30.3
BWI	BALTIMORE	MD	34.3	36.6	44.3	55.0	64.4	73.5	78.3	76.2	69.2	57.4	46.9	38.6
SBY	SALISBURY	MD	36.8	38.7	45.3	55.1	63.8	72.7	77.9	75.8	69.7	58.5	48.2	40.6
BOS	BOSTON	MA	29.9	31.8	38.3	48.6	58.4	68.0	74.1	72.7	65.6	54.8	44.7	35.7
CHH	CHATHAM	MA	32.1	32.7	37.6	45.6	55.0	64.3	71.4	70.6	64.3	54.3	45.4	37.3
ORH	WORCESTER	MA	24.7	27.0	34.5	46.1	56.7	65.2	70.8	69.3	61.9	50.6	40.2	30.5
APN	ALPENA	MI	20.0	20.7	29.3	41.2	53.4	63.2	68.2	66.6	59.0	47.4	36.6	26.6
DTW	DETROIT	MI	25.8	28.0	37.2	48.9	60.3	69.9	74.1	72.3	64.9	53.0	41.2	31.3
FNT	FLINT	MI	23.0	24.7	34.2	46.0	57.4	67.1	70.9	69.1	61.7	50.2	38.8	28.7
GRR	GRAND RAPIDS	MI	24.8	26.6	35.7	47.6	59.2	68.9	72.8	71.1	63.5	51.5	40.0	30.4
CMX	HANCOCK	MI	16.1	17.0	25.2	37.2	50.2	59.7	65.0	64.2	56.4	44.0	32.0	21.9
HTL	HOUGHTON LAKE	MI	19.1	20.3	29.7	42.2	54.7	63.9	67.8	65.8	58.3	46.8	35.5	25.6
JXN	JACKSON	MI	24.4	26.6	36.0	47.8	58.8	68.0	71.6	69.9	62.6	51.2	39.9	29.9
LAN	LANSING	MI	23.9	25.9	35.2	47.0	58.4	68.0	71.8	70.0	62.5	50.8	39.5	29.5
SAW	MARQUETTE	MI	18.5	19.7	28.2	38.4	49.8	59.0	66.2	66.2	59.4	47.0	34.5	24.4
MKG	MUSKEGON	MI	26.6	27.7	35.7	46.8	57.9	67.4	71.9	70.8	63.5	51.9	41.0	31.9
MBS	SAGINAW	MI	23.0	24.5	34.0	45.9	58.2	68.1	71.7	69.7	62.5	50.8	39.0	28.9
ANJ	SAULT ST MARIE	MI	16.2	17.8	26.7	39.4	52.1	61.1	66.0	65.6	58.4	46.3	34.8	23.8
TVC	TRAVERSE CITY	MI	23.1	23.8	32.2	43.4	55.3	65.6	70.3	69.2	61.9	49.9	38.7	29.1
AXN	ALEXANDRIA	MN	10.7	14.9	28.0	42.5	55.9	66.0	70.6	68.5	60.0	45.7	30.3	16.9
DLH	DULUTH	MN	11.2	15.4	27.0	39.5	52.0	61.2	67.0	65.5	57.2	44.1	29.8	17.1
HIB	HIBBING	MN	6.2	10.5	23.8	37.1	49.5	58.9	63.5	61.6	53.0	40.2	25.6	12.3
INL	INT'L FALLS	MN	5.0	9.5	23.6	38.1	51.1	60.8	64.9	62.8	54.2	41.1	26.3	11.8
MSP	MINNEAPOLIS	MN	16.2	20.6	33.3	47.1	59.5	69.7	74.3	71.8	63.5	49.5	34.8	22.0
RST	ROCHESTER	MN	14.7	18.7	31.7	45.2	57.6	67.5	70.5	68.2	61.1	47.9	33.6	20.8
STC	SAINT CLOUD	MN	11.8	16.1	29.2	43.3	56.2	66.0	70.3	67.7	59.5	45.7	30.9	17.8

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
GWO	GREENWOOD	MS	44.4	48.3	56.1	64.0	72.3	79.0	81.5	81.1	75.6	64.9	53.8	47.1
JAN	JACKSON	MS	47.0	50.9	57.9	64.9	72.9	79.6	82.1	81.8	76.9	66.2	55.4	49.1
MCB	MCCOMB	MS	49.1	53.0	59.5	65.5	73.1	79.2	81.1	81.0	76.9	67.5	56.9	51.1
MEI	MERIDIAN	MS	47.7	51.7	58.5	65.4	73.3	80.0	82.7	82.2	77.3	66.6	55.8	49.9
TUP	TUPELO	MS	43.4	47.3	55.1	63.3	71.8	79.2	82.3	81.6	75.5	64.4	53.0	45.9
COU	COLUMBIA	MO	31.0	35.7	46.0	56.4	65.8	74.6	78.5	77.2	69.2	57.5	45.3	35.2
JLN	JOPLIN	MO	33.7	37.9	47.8	57.0	65.4	74.2	78.2	76.9	68.6	57.8	46.4	36.5
MCI	KANSAS CITY	MO	29.0	33.6	44.5	54.6	64.6	74.1	78.2	76.7	68.4	56.4	43.6	33.1
STL	SAINT LOUIS	MO	32.1	36.7	46.6	57.5	67.5	76.5	80.4	78.8	71.0	59.1	46.5	36.5
SGF	SPRINGFIELD	MO	34.3	38.7	47.6	57.0	66.0	74.9	79.2	78.2	70.3	58.6	46.7	37.4
BIL	BILLINGS	MT	27.0	29.4	38.0	45.8	55.3	64.7	73.3	71.6	61.4	47.9	36.2	27.6
BTM	BUTTE	MT	20.0	22.2	31.6	38.7	47.6	55.5	63.6	61.8	52.8	40.6	27.8	19.0
CTB	CUT BANK	MT	21.8	23.1	31.1	40.2	49.6	57.6	64.9	63.9	54.4	42.0	30.6	22.8
GGW	GLASGOW	MT	14.6	18.7	31.6	44.8	55.5	64.5	72.0	71.0	59.9	45.2	30.2	18.5
GTF	GREAT FALLS	MT	25.2	26.2	34.1	42.4	51.5	59.4	67.9	66.7	57.2	44.8	33.6	26.0
HVR	HAVRE	MT	17.7	21.3	32.0	44.0	53.9	62.1	69.8	68.4	57.7	44.1	30.9	21.1
HLN	HELENA	MT	23.0	27.2	36.1	44.5	53.9	61.7	70.6	68.8	58.9	45.5	32.8	23.4
FCA	KALISPELL	MT	23.7	26.8	34.5	42.7	51.6	57.6	64.9	63.7	54.3	41.6	31.4	24.1
LWT	LEWISTOWN	MT	24.9	24.0	31.5	37.3	46.3	53.7	60.9	60.6	52.2	40.6	31.2	24.0
MLS	MILES CITY	MT	19.5	23.6	34.7	45.5	55.5	65.6	74.2	72.5	61.2	46.4	32.7	22.4
MSO	MISSOULA	MT	24.8	29.0	37.4	44.2	53.0	59.7	68.4	67.2	57.5	44.1	32.3	24.4
GRI	GRAND ISLAND	NE	25.9	29.7	40.7	51.0	62.0	72.8	77.0	74.6	66.6	53.1	39.6	28.9
LNK	LINCOLN	NE	25.0	29.5	41.2	52.0	63.1	73.7	78.1	75.6	67.2	53.8	39.8	28.8
OFK	NORFOLK	NE	22.3	26.3	37.8	48.9	60.1	70.4	74.8	72.4	64.4	50.8	36.8	25.7
LBF	NORTH PLATTE	NE	26.3	29.4	39.6	48.2	58.5	69.7	75.6	73.0	64.2	50.2	37.0	27.5
OMA	OMAHA	NE	24.4	28.9	41.0	52.6	63.6	73.9	78.1	75.7	67.6	54.4	40.2	28.7
BFF	SCOTTSBLUFF	NE	28.3	30.8	39.9	47.5	57.7	68.7	75.3	73.0	63.5	49.3	37.2	28.0
VTN	VALENTINE	NE	24.5	27.6	37.6	47.2	58.1	69.0	75.7	73.6	64.2	49.3	36.2	26.3
EKO	ELKO	NV	27.0	31.6	39.9	45.6	54.2	63.2	71.9	69.6	60.3	47.4	35.9	26.7
ELY	ELY	NV	26.7	30.0	37.7	43.2	51.5	61.3	69.3	67.5	58.4	46.4	35.1	26.2
LAS	LAS VEGAS	NV	49.5	53.5	60.8	67.7	77.3	87.6	93.2	91.7	83.6	70.4	57.2	48.2
LOL	LOVELOCK	NV	31.2	36.6	43.3	49.3	58.9	67.8	75.9	72.9	63.6	50.8	38.2	30.2
RNO	RENO	NV	36.9	40.6	46.6	51.6	60.3	69.2	77.2	75.1	67.0	55.1	43.8	36.2
TPH	TONOPAH	NV	33.9	37.2	43.8	49.9	59.0	69.1	75.7	73.7	65.7	53.5	41.0	32.5
WMC	WINNEMUCCA	NV	32.2	36.6	42.6	47.6	56.4	65.4	74.5	71.6	62.1	49.4	38.6	30.7
CON	CONCORD	NH	22.3	24.7	33.4	45.4	56.7	65.8	71.1	69.5	61.4	49.3	38.6	28.3
LEB	LEBANON	NH	19.8	22.4	31.9	44.3	56.7	65.1	70.3	68.6	60.7	48.6	37.2	26.8
MWN	MT WASHINGTON	NH	5.8	5.9	12.9	23.7	36.3	45.5	49.9	48.7	43.1	31.3	20.8	11.8
ACY	ATLANTIC CITY	NJ	34.1	36.0	42.6	52.5	61.9	71.4	76.9	75.0	68.4	57.1	46.8	38.7
EWR	NEWARK	NJ	32.8	35.1	42.5	53.3	63.3	72.7	78.2	76.4	69.2	57.5	47.0	38.0
ABQ	ALBUQUERQUE	NM	37.4	41.9	49.5	56.8	66.1	76.1	78.9	76.9	70.3	58.4	45.7	36.9
CNM	CARLSBAD	NM	43.9	48.4	55.6	63.7	72.6	81.0	82.3	81.0	73.9	63.3	51.4	43.5
CAO	CLAYTON	NM	35.5	37.5	44.9	52.0	61.5	71.2	75.4	73.1	66.4	54.7	43.7	35.3
GUP	GALLUP	NM	29.8	34.4	40.6	47.0	55.6	65.7	71.7	69.7	62.2	49.7	38.0	29.5
ROW	ROSWELL	NM	42.7	47.8	55.2	63.2	72.3	81.0	83.2	81.6	74.4	63.2	51.0	42.4
CVN	TUCUMCARI	NM	38.6	42.5	50.0	57.7	67.1	77.2	80.6	78.6	71.4	59.2	47.3	38.6
ALB	ALBANY	NY	24.4	26.8	35.7	48.1	59.6	68.4	73.1	71.4	63.5	51.4	40.5	30.4
BGM	BINGHAMTON	NY	22.5	24.5	32.3	44.6	56.2	64.4	68.9	67.3	60.0	48.8	37.9	28.1
BUF	BUFFALO	NY	25.5	26.4	34.1	45.6	57.9	66.9	71.7	70.4	63.4	51.7	41.0	31.4
GFL	GLENS FALLS	NY	19.7	21.9	31.7	44.6	56.5	65.0	69.7	67.8	59.7	48.0	37.2	26.6
MSS	MASSENA	NY	15.6	17.8	28.5	42.9	55.9	64.8	69.5	67.5	59.5	47.5	35.8	23.8
LGA	NEW YORK	NY	34.4	36.3	43.1	53.6	63.7	73.4	79.2	77.7	70.8	59.6	49.1	40.0
ROC	ROCHESTER	NY	26.2	27.4	35.2	46.8	58.8	67.6	72.3	70.7	63.6	52.2	41.5	32.0
SYR	SYRACUSE	NY	24.1	25.5	33.8	46.3	58.2	67.0	71.8	70.4	62.9	51.3	40.5	30.4
UCA	UTICA	NY	21.7	23.6	31.8	44.6	56.8	65.5	70.0	68.4	61.3	50.0	38.5	28.2
ART	WATERTOWN	NY	19.9	21.1	30.4	43.1	55.0	63.8	69.0	67.5	60.0	48.8	38.0	27.3
AVL	ASHEVILLE	NC	38.7	42.1	48.4	57.0	64.8	71.8	75.1	74.0	68.3	57.9	47.8	41.4
HAT	CAPE HATTERAS	NC	48.0	49.1	53.8	61.8	69.7	77.5	81.3	80.7	76.9	68.2	58.7	52.1
CLT	CHARLOTTE	NC	42.1	45.7	52.7	61.1	69.0	76.6	80.1	78.6	72.7	61.9	51.4	44.7
GSO	GREENSBORO	NC	46.4	50.1	56.5	63.3	71.0	77.8	80.6	80.2	75.3	65.2	54.4	48.1
HKY	HICKORY	NC	39.7	43.0	50.1	58.8	66.8	74.3	77.7	76.4	70.4	59.6	49.3	42.2
EWN	NEW BERN	NC	44.5	47.1	53.2	61.8	69.5	77.0	80.4	78.9	74.2	64.2	54.2	47.7
RDU	RALEIGH DURHAM	NC	41.9	45.0	51.8	60.8	68.8	76.7	80.5	78.8	72.6	61.7	51.5	44.6
ILM	WILMINGTON	NC	46.8	49.3	55.3	63.6	71.1	78.2	81.5	80.0	75.3	65.9	56.1	49.7

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BIS	BISMARCK	ND	12.8	17.5	30.1	43.2	55.3	65.4	71.3	69.6	59.7	44.8	29.9	17.9
P11	DEVIL'S LAKE	ND	7.2	11.2	24.1	41.1	54.6	64.6	69.4	68.0	58.8	43.6	26.5	13.3
DIK	DICKINSON	ND	14.6	18.6	29.1	41.2	52.7	62.4	69.1	67.9	57.5	42.9	29.6	18.4
FAR	FARGO	ND	9.2	13.4	27.2	43.0	56.6	66.8	70.7	68.8	60.0	45.5	29.5	15.7
GFK	GRAND FORKS	ND	6.3	10.6	24.4	40.7	54.1	64.6	68.9	67.0	57.9	43.2	26.7	12.8
JMS	JAMESTOWN	ND	9.4	13.0	26.3	39.9	52.7	62.8	68.6	67.1	57.7	42.7	27.8	15.1
MOT	MINOT	ND	13.8	17.3	29.2	43.5	56.1	65.6	71.2	70.1	60.1	45.6	30.2	18.3
ISN	WILLISTON	ND	11.6	16.1	28.8	42.4	53.8	63.5	70.4	69.0	58.0	43.2	27.8	16.1
CAK	AKRON CANTON	OH	27.9	30.2	38.9	50.8	61.3	69.9	73.9	72.3	65.4	53.7	42.5	33.0
CLE	CLEVELAND	OH	29.6	32.5	41.6	53.2	63.3	71.9	75.4	74.0	67.2	55.2	43.6	34.5
CMH	COLUMBUS	OH	29.6	32.5	41.6	53.2	63.3	71.9	75.4	74.0	67.2	55.2	43.6	34.5
CVG	CINCINNATI	OH	29.1	32.2	41.2	52.7	62.5	70.9	73.6	72.0	65.6	54.5	42.9	34.0
DAY	DAYTON	OH	29.4	32.8	42.1	53.7	64.0	72.7	76.0	74.5	67.7	56.0	44.1	34.3
FDY	FINDLAY	OH	27.8	30.5	39.7	51.4	62.5	71.7	74.9	72.9	66.4	54.8	42.9	33.0
MFD	MANSFIELD	OH	26.5	29.1	37.8	49.7	60.3	69.0	72.6	71.0	64.4	53.0	41.5	31.8
TOL	TOLEDO	OH	27.5	29.9	39.2	50.9	62.1	71.6	75.4	73.5	66.4	54.6	42.8	32.8
YNG	YOUNGSTOWN	OH	26.8	29.0	37.2	49.1	59.3	67.5	71.5	69.9	63.2	52.2	41.5	32.1
LHQ	ZANESVILLE	OH	30.1	32.9	41.6	52.8	62.3	70.5	74.2	72.7	65.9	54.3	43.4	34.7
GAG	GAGE	OK	36.6	40.0	49.7	58.3	68.0	77.5	82.0	80.6	72.4	59.8	47.2	37.4
HBR	HOBART	OK	39.4	43.4	51.9	60.1	70.4	80.2	84.7	83.4	75.1	62.9	50.2	40.9
MLC	MCALESTER	OK	41.1	45.5	53.9	61.7	69.9	78.2	82.6	81.9	74.3	63.3	52.1	43.3
OKC	OKLAHOMA CITY	OK	38.2	42.3	51.2	59.3	68.2	76.9	81.7	80.7	72.7	61.1	49.2	40.0
PNC	PONCA CITY	OK	35.9	40.1	49.5	58.5	68.1	77.6	82.4	80.9	72.7	60.5	48.1	38.1
TUL	TULSA	OK	38.5	42.8	52.0	60.8	69.6	78.6	83.4	82.2	73.8	62.3	50.4	41.0
AST	ASTORIA	OR	43.7	44.2	46.0	48.7	53.4	57.3	60.6	61.3	59.0	52.8	46.9	43.2
BKE	BAKER	OR	28.8	33.5	40.8	45.9	54.2	60.6	68.5	67.7	59.1	47.1	36.2	28.6
BNO	BURNS	OR	26.5	31.0	38.7	43.9	52.8	59.7	68.6	66.5	57.8	45.6	34.7	25.9
EUG	EUGENE	OR	41.4	43.3	46.9	50.7	56.1	60.9	67.8	67.9	62.9	53.4	45.5	40.6
MFR	MEDFORD	OR	40.4	44.1	48.3	52.8	60.4	66.9	75.1	74.5	67.7	56.1	45.2	39.4
OTH	NORTH BEND	OR	47.3	47.6	48.5	50.4	54.2	57.4	59.8	60.4	59.0	54.9	50.2	46.7
PDT	PENDLETON	OR	34.9	38.0	44.4	50.1	57.9	64.6	73.0	71.8	63.5	51.5	40.7	34.2
PDX	PORTLAND	OR	41.9	44.1	48.3	52.8	59.4	64.2	70.2	70.6	65.4	55.6	47.1	41.6
RDM	REDMOND	OR	34.8	36.6	41.3	45.5	53.4	60.0	68.0	66.8	59.6	48.6	39.1	32.8
SLE	SALEM	OR	42.1	44.0	47.5	51.3	57.7	62.7	69.3	69.2	64.0	54.3	46.3	41.3
ABE	ALLENTOWN	PA	30.1	32.4	40.7	51.8	62.0	70.9	75.6	73.6	66.3	54.6	43.9	35.0
AOO	ALTOONA	PA	28.4	30.7	38.7	50.4	60.3	68.5	72.4	70.6	63.7	53.0	42.3	33.1
BFD	BRADFORD	PA	23.1	24.9	33.0	44.9	55.4	63.2	66.9	65.5	58.9	48.3	37.8	28.5
DUJ	DU BOIS	PA	24.5	26.8	35.2	47.2	57.4	65.1	69.1	67.7	61.0	50.1	39.2	29.8
ERI	ERIE	PA	28.2	28.9	36.1	47.4	58.8	68.2	72.7	71.5	65.2	54.3	43.6	34.1
CXY	HARRISBURG	PA	32.6	34.7	43.2	54.1	64.0	73.0	77.5	75.4	68.5	56.7	46.0	37.0
PHL	PHILADELPHIA	PA	33.7	35.9	43.6	54.5	64.3	73.5	78.7	76.8	69.9	58.2	47.4	38.6
PIT	PITTSBURGH	PA	28.8	31.4	39.7	51.5	61.2	69.4	73.2	71.8	64.9	53.4	42.6	33.7
AVP	SCRANTON	PA	28.0	30.3	38.3	50.2	60.9	69.0	73.7	71.8	64.6	53.2	42.7	33.3
IPT	WILLIAMSPORT	PA	27.7	30.1	38.7	50.3	60.8	69.4	73.7	72.0	64.7	53.0	41.9	32.8
PVD	PROVIDENCE	RI	30.2	32.0	38.9	49.3	59.1	68.2	74.4	73.0	65.6	54.4	44.5	35.5
CHS	CHARLESTON	SC	49.5	52.7	58.7	65.8	73.3	79.4	82.5	81.4	76.9	67.8	58.3	52.2
CAE	COLUMBIA	SC	45.7	49.1	55.9	64.1	72.2	79.1	82.4	81.0	75.5	64.6	54.0	47.7
FLO	FLORENCE	SC	46.6	49.7	56.3	64.4	72.2	79.1	82.2	80.9	75.6	65.5	55.3	48.9
GSP	GREENVILLE	SC	44.1	47.7	54.7	63.3	71.3	78.1	81.3	80.1	74.4	63.7	53.7	46.6
ABR	ABERDEEN	SD	12.8	17.5	30.5	44.5	57.3	67.6	72.3	69.7	60.9	46.3	30.9	18.3
HON	HURON	SD	16.0	20.5	32.9	45.7	57.9	68.3	73.7	71.3	62.6	47.9	33.1	20.6
PIR	PIERRE	SD	19.1	23.2	34.3	45.9	57.2	67.8	74.9	73.0	63.6	48.5	34.1	22.8
RAP	RAPID CITY	SD	24.3	26.1	35.4	43.9	54.1	64.6	72.4	70.8	61.3	47.1	34.6	25.6
FSD	SIOUX FALLS	SD	17.9	22.3	34.7	47.2	59.1	69.9	74.4	72.0	63.8	49.6	34.8	22.5
ATY	WATERTOWN	SD	12.2	16.3	29.1	42.8	55.7	66.1	71.0	68.5	60.1	45.7	30.6	17.8
TRI	BRISTOL	TN	36.4	40.0	47.4	56.4	64.7	72.3	75.6	74.5	68.6	57.3	46.4	39.3
CHA	CHATTANOOGA	TN	41.7	45.6	53.2	61.7	70.0	77.4	80.7	80.0	73.9	62.7	51.2	44.3
CSV	CROSSVILLE	TN	35.3	38.8	46.0	55.4	63.2	70.2	73.8	72.9	67.0	56.4	46.0	38.8
MKL	JACKSON	TN	39.0	42.7	50.9	60.3	68.9	76.4	79.5	78.3	71.7	60.7	49.3	41.8
TYS	KNOXVILLE	TN	39.1	42.9	50.6	59.6	67.9	75.3	78.5	77.6	71.8	60.3	49.0	41.9
MEM	MEMPHIS	TN	42.1	46.1	54.2	63.2	72.1	79.9	82.8	82.1	76.0	64.6	52.7	44.8
BNA	NASHVILLE	TN	39.6	43.4	51.5	60.8	69.3	77.1	80.7	79.7	73.1	61.7	50.3	42.7
ABI	ABILENE	TX	46.3	50.1	58.1	66.0	74.1	81.1	84.7	84.2	76.8	67.0	55.5	47.3
ALI	ALICE	TX	57.0	61.3	67.3	73.5	79.4	84.0	85.4	86.0	81.5	74.3	65.3	58.8

Station Location			30-year Mean Temperature 1991-2020 NOAA											
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AMA	AMARILLO	TX	38.6	41.8	49.8	57.5	66.8	76.1	79.6	78.1	70.9	59.2	47.4	38.8
AUS	AUSTIN	TX	50.1	54.2	61.0	68.1	76.0	82.2	84.5	84.8	79.1	69.9	59.3	51.8
BRO	BROWNSVILLE	TX	62.8	66.5	71.3	76.7	82.0	85.6	86.4	87.0	83.4	77.9	70.5	64.4
CLL	COLLEGE STATION	TX	51.5	55.3	62.1	68.7	76.4	82.6	85.1	85.7	80.6	71.1	60.4	53.1
CRP	CORPUS CHRISTI	TX	58.0	61.9	67.4	73.4	79.0	83.2	84.6	85.4	81.9	75.1	66.2	59.7
DHT	DALHART	TX	36.3	39.5	47.2	55.0	64.9	74.9	78.7	76.9	69.5	57.1	45.1	36.1
DFW	DALLAS FT WORTH	TX	46.3	50.5	58.2	65.6	74.0	81.9	85.7	85.7	78.5	67.7	56.4	48.1
DRT	DEL RIO	TX	53.1	58.2	65.6	72.7	79.7	85.2	87.2	87.4	81.4	72.5	61.1	53.5
ELP	EL PASO	TX	46.5	51.5	58.7	66.6	75.4	83.9	84.4	82.9	76.9	66.7	54.5	46.1
GLS	GALVESTON	TX	56.0	59.3	65.2	71.5	78.2	83.8	85.5	85.9	82.4	75.3	65.5	58.5
IAH	HOUSTON	TX	53.8	57.7	63.8	70.0	77.4	83.0	85.1	85.2	80.5	71.8	62.0	55.4
LRD	LAREDO	TX	57.5	62.5	69.2	76.1	82.1	87.0	88.1	88.9	83.0	76.3	66.3	58.6
LBB	LUBBOCK	TX	41.1	45.1	53.0	61.2	70.4	78.6	81.2	79.9	72.3	61.8	50.0	41.7
LFK	LUFKIN	TX	48.6	52.8	59.4	66.0	73.8	79.9	82.5	82.4	77.3	67.4	57.0	50.2
MFE	MCALLEN	TX	62.8	67.2	72.9	78.4	83.6	87.7	88.6	89.3	85.0	79.0	70.2	64.0
MAF	MIDLAND ODESSA	TX	45.7	50.2	58.0	66.2	75.4	82.6	84.4	83.2	76.2	66.5	54.3	46.4
PSX	PALACIOS	TX	55.6	59.3	65.0	71.4	78.1	83.6	85.4	85.6	81.5	73.9	64.6	58.0
CXO	PORT ARTHUR	TX	53.7	57.5	63.3	69.3	76.5	82.0	83.6	83.8	80.0	71.6	61.9	55.6
SJT	SAN ANGELO	TX	47.4	51.5	59.4	67.1	75.5	82.2	84.8	84.1	77.0	67.1	55.9	48.4
SAT	SAN ANTONIO	TX	52.2	56.3	62.8	69.4	76.5	82.6	84.8	85.5	79.9	71.3	60.7	53.5
VCT	VICTORIA	TX	54.4	58.4	64.4	70.4	77.3	82.7	84.5	84.8	80.4	72.6	62.8	56.2
ACT	WACO	TX	47.4	51.6	58.8	66.2	74.3	81.9	85.6	85.5	78.7	68.4	57.2	49.2
SPS	WICHITA FALLS	TX	42.4	46.3	54.7	62.8	71.8	80.1	84.7	84.1	76.0	64.6	52.7	43.7
CDC	CEDAR CITY	UT	30.4	34.3	41.5	47.2	56.4	66.6	74.0	72.1	63.1	50.5	38.5	29.2
SLC	SALT LAKE CITY	UT	31.4	36.6	45.8	51.8	61.5	71.6	81.1	79.1	68.4	54.6	41.7	32.2
BTV	BURLINGTON	VT	20.9	22.9	32.3	45.6	58.4	67.5	72.4	70.7	62.7	50.3	39.3	28.2
MPV	MONTPELIER	VT	16.6	18.9	27.9	40.9	53.3	61.8	66.5	64.9	57.4	45.5	34.4	23.2
LYH	LYNCHBURG	VA	35.9	38.8	46.4	56.1	64.2	72.0	76.0	74.5	68.0	57.0	46.5	38.9
ORF	NORFOLK	VA	42.2	44.2	50.7	60.1	68.3	76.7	81.1	79.2	74.0	63.7	53.3	46.1
RIC	RICHMOND	VA	38.3	41.0	48.4	58.4	66.7	75.0	79.4	77.5	71.2	60.0	49.6	41.8
ROA	ROANOKE	VA	37.9	40.8	48.3	58.0	66.1	73.8	77.8	76.2	69.6	58.9	48.4	40.9
BLI	BELLINGHAM	WA	40.2	41.7	45.1	49.6	55.5	59.8	63.9	63.9	58.9	51.1	44.5	39.8
HQM	HOQUIAM	WA	42.8	43.6	45.8	48.7	53.4	57.1	60.3	61.0	59.1	52.5	45.9	42.0
OLM	OLYMPIA	WA	39.6	40.7	44.1	48.2	54.5	59.1	64.2	64.2	59.1	50.3	43.2	38.9
UIL	QUILLAYUTE	WA	41.7	42.1	43.9	46.9	51.7	55.5	59.3	60.0	57.1	50.6	44.7	41.0
SEA	SEATTLE TACOMA	WA	42.8	44.0	47.1	51.3	57.5	62.0	67.1	67.4	62.6	53.8	46.5	42.0
GEG	SPOKANE	WA	29.6	32.9	40.0	47.0	56.0	62.3	71.0	70.3	61.1	47.9	36.3	29.1
ALW	WALLA WALLA	WA	36.3	39.7	46.8	52.5	60.4	67.0	76.3	75.2	66.2	53.7	42.4	35.6
EAT	WENATCHEE	WA	28.9	34.5	43.1	51.1	60.1	66.5	74.7	73.7	64.6	50.7	37.4	29.0
YKM	YAKIMA	WA	31.7	36.6	43.4	49.9	58.8	65.1	72.4	70.9	62.2	49.8	38.0	30.6
BKW	BECKLEY	WV	32.2	35.4	42.8	53.5	61.3	68.2	71.6	70.5	64.7	54.3	44.0	36.0
CRW	CHARLESTON	WV	35.0	38.2	46.0	56.9	64.7	72.3	75.8	74.6	68.3	57.0	46.4	38.7
EKN	ELKINS	WV	30.8	33.5	41.0	51.5	60.2	67.8	71.4	70.2	64.1	52.7	42.3	34.7
HTS	HUNTINGTON	WV	34.8	38.2	46.4	57.2	65.2	72.9	76.4	75.2	68.7	57.4	46.6	38.6
MRB	MARTINSBURG	WV	32.4	35.0	42.8	53.6	62.5	71.1	75.7	73.8	66.7	55.2	44.6	36.0
MGW	MORGANTOWN	WV	32.0	34.8	42.6	53.8	62.6	70.3	74.1	72.8	66.5	55.3	44.9	36.4
PKB	PARKERSBURG	WV	32.0	35.0	43.6	54.6	63.3	71.0	74.7	73.5	66.9	55.4	44.7	36.3
EAU	EAU CLAIRE	WI	14.6	18.8	31.2	44.8	57.4	67.1	71.3	69.1	60.8	47.5	33.4	20.6
GRB	GREEN BAY	WI	18.3	21.1	32.1	44.3	56.5	66.4	70.5	68.6	61.0	48.7	36.2	24.5
LSE	LACROSSE	WI	18.9	23.3	35.8	49.0	61.0	71.0	75.0	72.8	64.8	51.7	37.6	25.1
MSN	MADISON	WI	19.4	23.0	34.4	46.3	58.1	68.0	71.9	69.7	62.0	49.7	36.7	25.3
MKE	MILWAUKEE	WI	24.0	27.1	36.4	46.3	57.1	67.6	73.3	72.3	65.0	53.0	40.4	29.5
AUW	WAUSAU	WI	14.8	18.5	30.1	43.1	55.8	65.4	69.5	67.4	59.2	46.3	32.8	20.7
CPR	CASPER	WY	25.1	26.6	35.8	42.3	52.0	62.5	71.0	69.0	58.9	45.3	34.0	24.8
CYS	CHEYENNE	WY	29.2	29.5	37.1	42.8	52.3	63.1	70.1	68.1	59.6	46.5	36.1	28.7
COD	CODY	WY	27.5	28.6	37.7	44.2	53.1	62.4	70.6	68.9	59.7	46.9	35.2	27.3
LND	LANDER	WY	21.3	25.0	36.0	43.2	52.8	62.8	71.5	69.8	59.6	45.4	32.1	21.6
RKS	ROCK SPRINGS	WY	21.5	24.3	34.0	41.2	50.8	61.0	69.4	67.3	57.3	44.5	31.2	21.4
SHR	SHERIDAN	WY	24.0	26.0	35.7	43.2	52.4	61.8	70.7	69.1	59.1	45.4	33.3	24.5
WRL	WORLAND	WY	17.2	23.3	36.8	45.9	56.2	66.2	73.9	71.2	60.2	46.4	31.3	19.4

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *2015 Residential Energy Consumption Survey (RECS)*. 2015. (Last accessed March 1, 2023.) https://www.eia.gov/consumption/residential/data/2015/.

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3. National Oceanic and Atmospheric Administration. *Degree Days Archives - Weekly/Monthly Heating/Cooling Degree Days by City/State*. Weekly/Monthly Heating/Cooling Degree Days by City/State. (Last accessed March 1, 2023.) https://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/.

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APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET MODEL

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APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET MODEL

8A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on the U.S. Department of Energy's (DOE's) electric pool heater rulemaking website: https://www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44. From that page, follow the links to the Final Rule analysis rulemaking phase and then to Analytical Tools.

8A.2 STARTUP

DOE's spreadsheets enables users to perform life-cycle cost (LCC) and payback period (PBP) analyses for each product class. Three spreadsheets exist for both furnace product classes: a spreadsheet labeled "LCC", another labeled "Analysis Input", and another labeled "LCC Results". The Analysis Input spreadsheet contains the raw data used for the analysis as well the formulas that led to the processed data that are used in the LCC. The Analysis Input spreadsheet serves the purpose of delivering the raw input used in the analysis as well as of informing the public on how the processed data in the main LCC is derived for complete transparency. The LCC Results spreadsheet summarizes the LCC results as well as provides the LCC outputs for the NIA spreadsheet.

The three spreadsheets are independent. The main LCC spreadsheet can be downloaded and run separately. To change the input of the main LCC based or updated data from the Analysis Input spreadsheet, the user will need to manually copy/paste the data that was modified in the Analysis Input spreadsheet into the main LCC spreadsheet. Finally, to populate the results in the LCC Results spreadsheet, the user will need to manually copy/paste the updated extracted forecast cells from the main LCC spreadsheet into the LCC Results spreadsheet.

To examine the spreadsheets, DOE assumed that the user has access to a personal computer with hardware capable of running Windows XP or later. All spreadsheets require Microsoft Excel 2003 or later installed under the Windows operating system. Crystal Ball[a] (a commercially available Excel add-on program) is also needed to regenerate the LCC results and to view the statistical distributions that are used to define certain variables inside the spreadsheets.

8A.3 DESCRIPTION OF LIFE-CYCLE COST WORKSHEET

8A.3.1 LCC Worksheet

For both of the pool heater product classes, DOE created a single LCC spreadsheet containing a collection of worksheets. Each worksheet represents a conceptual component within the LCC calculation. To facilitate navigability and identify how worksheets are related, each

[a] See www.oracle.com/us/products/applications/crystalball/overview/index.html

worksheet contains an area on the extreme left showing variables imported to and exported from the current worksheet. The LCC spreadsheet contains the following worksheets:

Introduction	The *Introduction* worksheet contains an overview of each worksheet and a flow chart of the inputs and outputs of the spreadsheet.
Statistics	The *Statistics* worksheet contains the statistics of key parameters from the outcome of the Monte Carlo simulations for the sample of households or buildings.
Summary	The *Summary* worksheet contains a user interface to manipulate energy price trends and start year inputs, and to run the Crystal Ball simulation. LCC and PBP simulation results for each efficiency level are also displayed here.
LCC&PB Calcs	The *LCC&PB Calcs* worksheet shows LCC calculation results for different efficiency levels for a single Energy Information Administration's (EIA's) *2015 Residential Energy Consumption Survey* (RECS 2015)[1] household and EIA's *2012 Commercial Building Energy Consumption Survey* (CBECS 2012)[2] building. During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household or building.
Rebuttable Payback	The *Rebuttable Payback* worksheet contains the total and incremental manufacturer costs, retail prices, installation costs, repair and maintenance costs, energy use calculations, and the simple PBP calculations for each efficiency level. DOE's residential furnace and furnace test procedure is used to calculate parameters used in energy use calculations.
Prod Price	The *Prod Price* worksheet calculates retail price values used as inputs in the LCC calculations in the *Summary* worksheet.
Markups	The *Markups* worksheet calculates markup values used as inputs in the *Prod Price* worksheet. DOE applied baseline and incremental markups to calculate final retail prices. DOE calculated the markups differently for replacement units and new units.
Prod Price Trend	The *Prod Price Trend* worksheet calculates projected product price trend scenarios used to adjust the manufacturer's cost over the entire analysis period as inputs in the *Prod Price* worksheet.
Installation Cost	The *Installation Cost* worksheet provides the weighted average installation cost for each design option. These results are used to calculate the total installed prices of the design options.
Installation Cost Data	The *Installation Cost Data* worksheet provides the data inputs to the installation cost calculations.
Maint & Repair Cost	The *Maint & Repair Cost* worksheet provides the maintenance and repair costs for each design option. These results are used to determine operating costs for the design options.
Labor Costs	The *Labor Cost* worksheet provides the labor cost by region as used to determine the installation and repair/maintenance costs.

Bldg Sample	The *Bldg Sample* worksheet contains the RECS 2015 and CBECS 2012 data for each product class. During a Crystal Ball simulation, DOE uses these characteristics to determine the analysis parameters.
No-New Standards Case TEi	The *No-New Standards Case TEi* worksheet includes the pool heater efficiency distribution for 2028.
Energy Use	The *Energy Use* worksheet calculates annual energy use by fuel type, depending on product class. The annual energy use calculations for each design option are inputs to the *LCC&PB Calcs* worksheet to calculate the annual operating cost of the LCC.
Energy Price (Base Year)	The *Energy Price (Base Year)* worksheet shows the estimated monthly natural gas, electricity, and oil prices.
Energy Price Trends	The *Energy Price Trends* worksheet shows the future price trends of the different heating fuels. DOE used energy price data and forecasts from the Energy Information Administration's (EIA's) Annual Energy Outlook 2022 for the period until 40 and extrapolated beyond 2050.[3]
Discount Rate	The *Discount Rate* worksheet contains the distributions of discount rates for replacement and new units.
Lifetime	The *Lifetime* worksheet contains the distribution of lifetimes for products of that product class.
Weather Data	The *Weather Data* worksheet contains weather data for each weather station mapped to a household or building.
Labels	The *Labels* worksheet contains labels used in graphical user interface.
Forecast Cells	The *Forecast Cells* worksheet contains the outcome of the Monte Carlo simulations for the sample of 10,000 households and commercial buildings for many parameters used in the analysis and the documentation.

8A.3.2 LCC Results Spreadsheet

The *LCC Results* spreadsheet contains all the LCC results, as well as intermediate inputs used for DOE's National Impact Analysis. These inputs include fuel and electricity use, total installed price, operating cost, base case distributions, and fuel switching impact for each product class and efficiency level. The inputs are presented for replacement and new construction housing markets, as well as Residential and Commercial.

8A.4 BASIC INSTRUCTIONS FOR OPERATING THE LIFE-CYCLE COST SPREADSHEETS

Basic instructions for operating the LCC spreadsheet are as follows:

1. Once the LCC spreadsheet has been downloaded, open the file using Excel. Click "Enable Macro" when prompted and then click on the tab for the *Summary* worksheet.
2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to fit your monitor.
3. The Analysis User Variables listed on the *Summary* worksheet are:
    a. Start Year: Default is "2028." Changing the start year does not update the inputs, and thus only gives an approximation of the results for a different start year. To change the value, type in the desired year.
    b. # of Trials: Default is "10,000." To change the value, type in the desired number of trials for Crystal Ball to run. Decreasing the number of runs will increase the speed of the simulation but decrease the representativeness of the results.
4. The user can change the parameters listed under Scenarios in the *Summary* worksheet. There are three drop-down boxes and one command button. The default parameters are:
    a. Energy Price Trend: set to "AEO 2022 - Reference Case." To change the input, use the drop-down menu and select the desired trend (Reference, Low, or High).
    b. Product Price Trend: set to "No Learning (Constant)." To change the value, use the drop-down menu and select the desired product price trend ("No Learning (Constant)," "Increasing", or "Decreasing").

5. To run the Crystal Ball simulation, click the "Run" button (you must re-run after changing any parameters). The spreadsheet will then be minimized. You can monitor the progress of the simulation by watching the count of iterations at the left bottom corner. When the simulation is finished, the worksheet named *Summary* will reappear with the results.

To populate the LCC Results spreadsheet, click on "Crystal Ball" menu and then on "Extract Forecast Cells". Select in the "Data" tab: 1) Select data to extract: "Trial values"; 2) Forecast cells: "Choose…"; and 3) Assumptions: "None". Then click ok, which will generate a new spreadsheet with the forecast cells. Proceed to copy and paste the forecast cells into the "Data" worksheet of the LCC Results spreadsheet.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *2015 Residential Energy Consumption Survey (RECS)*. 2015. (Last accessed March 1, 2023.) https://www.eia.gov/consumption/residential/data/2015/.

2. U.S. Department of Energy–Energy Information Administration. *2012 Commercial Buildings Energy Consumption Survey (CBECS)*. 2012. (Last accessed March 1, 2023.) https://www.eia.gov/consumption/commercial/data/2012/.

3. U.S. Department of Energy–Energy Information Administration. *Annual Energy Outlook 2022*. 2022. Washington, D.C. (Last accessed March 1, 2023.) https://www.eia.gov/outlooks/aeo/.

APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8B.1 INTRODUCTION

This appendix discusses uncertainty and variability and describes how the U.S. Department of Energy (DOE) incorporated these into the life-cycle cost (LCC) and payback period (PBP) analysis in this technical support document (TSD) for the oil, electric, and weatherized gas consumer furnaces energy conservation standards (ECS) rulemaking. The two key approaches are (1) to use distributions to capture uncertainties and variations in input variables when such distributions are reasonably well defined, and (2) to use scenarios that capture the bounds of uncertainty when the bounds are less well defined.

8B.2 UNCERTAINTY AND VARIABILITY

DOE develops mathematical models to analyze the impacts of proposed energy conservation standards. The models generate outputs (*e.g.,* the LCC impact of proposed standards) based on inputs that are often uncertain, variable, or both.

Variability means that the quantity of interest takes on different values at different times or under different conditions. Variability may be caused by many factors. For example, the hours of use of a lamp depend on environmental factors (*e.g.,* diurnal variations in light) and behavioral factors (*e.g.*, the schedules and preferences of the inhabitants of a house). Manufacturing irregularities can also cause variability. For example, 10 lamps of the same model may each have slightly different power consumptions. DOE attempts to account for major sources of variability in its analyses.

Uncertainty has many sources. Variability may lead to uncertainty in model inputs, because analysts frequently must estimate the values of interest based on samples of a variable quantity (for example, the hours of use of lighting in a home). Measurement uncertainty is another source of uncertainty, which may result from instrumental uncertainties (resulting, for example, from drift, bias, and precision of resolution) and human factors (*e.g.,* variations in experimental setup, errors in instrument readings or recordings). Uncertainty can also arise when there is limited data available to estimate a particular parameter. DOE attempts to address the major sources of uncertainties in its analyses.

8B.2.1 Approaches to Uncertainty and Variability

This section describes two approaches to address uncertainty and variability in numerical modeling that in practice are often used in tandem, as they are in this rulemaking: (1) probability analysis and (2) scenario analysis.

Probability analysis considers the probability that a variable has a given value over its range of possible values. For quantities with variability (*e.g.,* electricity rates in different households), data from surveys or other forms of measurement can be used to generate a frequency distribution of numerical values to estimate the probability that the variable takes a given value. By sampling values from the resulting distribution, it is possible to quantify the impact of known variability in a particular variable on the outcome of the analysis. In this analysis, DOE used probability distributions to estimate oil, electric, and weatherized gas consumer furnaces lifetime, discount rates, and other variables.

Unlike probability analysis, which considers the impact of known variability, scenario analysis estimates the sensitivity of an analysis to sources of uncertainty and variability whose probability distribution is not well known. Certain model inputs are modified to take a number of different values, and models are re-analyzed, in a set of different model scenarios. Because only selected inputs are changed in each scenario, the variability in the results for each scenario helps to quantify the impact of uncertainty in the input parameters. Whereas it is relatively simple to perform scenario analyses for a range of scenarios, scenario analyses provide no information regarding the likelihood of any given scenario's actually occurring.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.3 PROBABILITY ANALYSIS AND THE USE OF MONTE CARLO SIMULATION IN THE LCC AND PBP ANALYSES

To quantify the uncertainty and variability that exist in inputs to the LCC and PBP analyses, DOE used Monte Carlo simulation and probability distributions to conduct probability analyses.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a model will only reveal a single outcome, generally the most likely or average scenario. Probabilistic risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on the outputs of a modeled system. One type of simulation is Monte Carlo simulation, which repeatedly generates random values for uncertain variables, drawn from a probability distribution, to simulate a model.

For each uncertain variable, the range of possible values is controlled by a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include normal, triangular, uniform, and Weibull distributions, as well as custom distributions where needed. Example plots of these distributions are shown in Figure 8B.3.1.

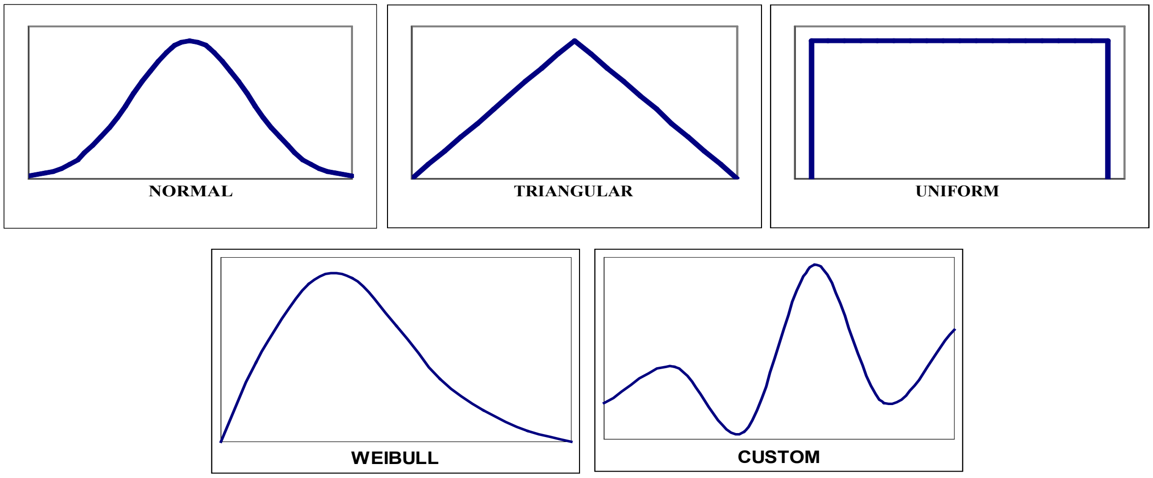

Figure 8B.3.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for that input. Monte Carlo simulations can consist of as many trials as desired, with larger numbers of trials yielding more accurate average results. During a single trial, the simulation randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the result for that trial.

DOE conducted probability analyses using Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in software. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. To calculate the LCC and PBP for oil, electric, and weatherized gas consumer furnaces, DOE performed 10,000 Monte Carlo simulations for each variable. During a single trial, Crystal Ball randomly selected a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculated the spreadsheet.

APPENDIX 8C. FORECAST OF PRODUCT PRICE TRENDS FOR POOL HEATERS

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APPENDIX 8C. FORECAST OF PRODUCT PRICE TRENDS FOR POOL HEATERS

8C.1 INTRODUCTION

DOE did not find any historical producer price indices (PPI) for pool heaters to study the historical price trend for pool heaters. DOE examines historical distributor prices for pool heaters at different ratings spanning the time period 2003-2021 from the 2022 Pkdata.[1] For this product, DOE found consistent negative real price trends. Therefore, DOE concluded that the real prices of pool heaters have a different long term trend than prices in the economy as a whole. In this analysis, DOE concluded that the manufacturer selling prices of products meeting various efficiency levels may not remain fixed, in real terms, after 2021 (the year for which the engineering analysis estimated costs). DOE maintained the constant real price trend as a sensitivity analysis to evaluate how the impact of potential standards might change under this scenario.

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that an assumption of constant real prices may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may, in fact, trend downward over time according to "learning" or "experience" curves. Desroches *et al*. (2013) summarizes the data and literature that is relevant to price projections for selected appliances and equipment.[2] The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[a]

Due to the relatively limited historical pool heater prices, DOE used the inflation-adjusted prices to fit an exponential model with *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

Eq. 8.1

Where:

Y = the deflated pool heater prices,
a = the constant,
b = the slope parameter of the time variable, and
X = the time variable.

In light of these data and DOE's aim to improve the accuracy and robustness of its analyses, DOE decided to assess future costs by incorporating a price trend over time, consistent with the analysis in the available literature. DOE used this approach to project future prices of EPHs and GPHs in the rulemaking analysis.

[a] In addition to Desroches (2013), see Weiss, et al (2010). [3]

8C.2 PRICE, COST, AND MARKET STRUCTURE

DOE uses a cost-based analysis in estimating equipment prices. To estimate equipment prices in both the standards and the baseline or no-new-standard case, DOE develops engineering cost estimates that DOE then uses to estimate manufacturer selling price. The manufacturer selling price includes direct manufacturing production costs (labor, material, and overhead estimated in DOE's manufacturer production costs) and all non-production costs (SG&A, R&D, and interest), along with profit. The process of the cost-based method for developing the manufacturer selling prices is described in the engineering analysis in chapter 5 of this TSD. To convert the manufacturer selling price to an equipment price for the consumer, DOE performs an analysis of distribution chain markups and estimates markups on both the baseline and incremental manufacture selling prices to determine equipment prices after distribution to the consumer.

In analyzing experience curves to estimate price trends, DOE uses producer price indices as a key data input and analyzes this data to estimate the experience curve exponent. This approach has only one model parameter to describe the price trend and assumes a simple relationship between producer price and retail equipment price. Specifically, the approach assumes that producer prices, distribution chain markups and equipment prices all scale proportionally over time for the same product.

DOE could have developed a more complex price trend forecasting model with more parameters that could explain different trends in different equipment price and cost components over time. But the relatively few available data points present a risk that a fit with multiple parameters would "overfit" the data. Overfitting occurs when there are too many degrees of freedom in a statistical model compared to the data and the fits are sensitive to random noise unrelated to long term trends. Due to the risk of overfitting the available data, DOE has decided to not develop a more complex multi-parameter price trend estimation model at this time.

Due to the simple nature of the price trend estimation model, there are several well-known economic and market phenomenon that will not be captured in detail by the price trend forecast. Some effects might lead to an overestimate of the long term price trend and other effects may lead to an underestimate. For example, if there has been increasing market concentration historically on the part of manufacturers, this may have resulted in increasing manufacturer and wholesale markups over time. This would result in an observed historical producer price trend that did not decrease as fast as the underlying industrial learning rate. Depending on if market concentration accelerated or decelerated into the future this could lead to an over- or under-estimation of future price trends.

Similarly, if there are cost components that have relatively slow long term price trends that have an increasing impact on price over time, the decreasing share of costs that are declining rapidly can result in a change in the empirically estimated experience curve exponent over time.

8C.3 DERIVATION OF LEARNING RATES

For electric pool heaters, DOE considered heat pump pool heaters as a design option to increase efficiency. The technology used in electric resistance pool heaters (ERPHs) has been widely applied and has already reached maturity, whereas heat pump pool heaters (HPPHs) use a more innovative technology that may be undergoing a much different experience curve than electric resistance pool heaters. Hence, DOE developed separate product price projections for baseline electric resistance pool heaters and heat pump pool heaters with higher efficiencies.

DOE obtained historical distributor prices for EPHs, HPPHs, and GPHs at different ratings spanning the time period 2003-2021 from the 2022 Pkdata.[1] DOE first averaged the prices across ratings within a product type to come up with an average price series for each product type. Then, the inflation-adjusted prices were calculated by dividing the average prices by the implicit price deflator for Gross Domestic Product (see Figure 8.2.1).

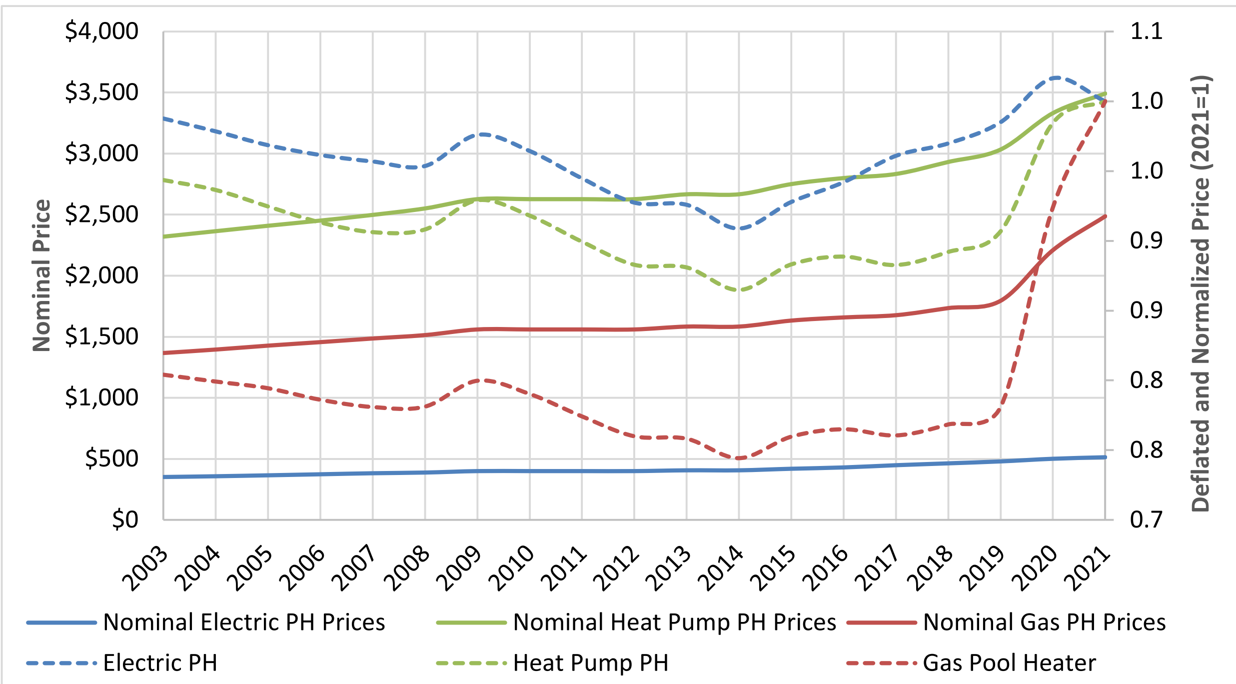

Figure 8C.3.1 Historical Nominal and Deflated Prices for Pool Heaters from 2003 to 2021

Due to the relatively limited historical pool heater prices, DOE used the inflation-adjusted prices to fit an exponential model with *year* as the explanatory variable. In this case, the exponential function takes the form of:

$$Y = a \cdot e^{bX}$$

Eq. 8.2

Where:

Y = the deflated pool heater prices,
a = the constant,
b = the slope parameter of the time variable, and
X = the time variable.

To estimate these exponential parameters for each product type, a least-square fit was performed on the inflation-adjusted pool heater prices versus *year* from 2003 to 2021 for ERPHs, HPPHs, and GPHs separately (see Figure 8C.3.2 to Figure 8C.3.4).

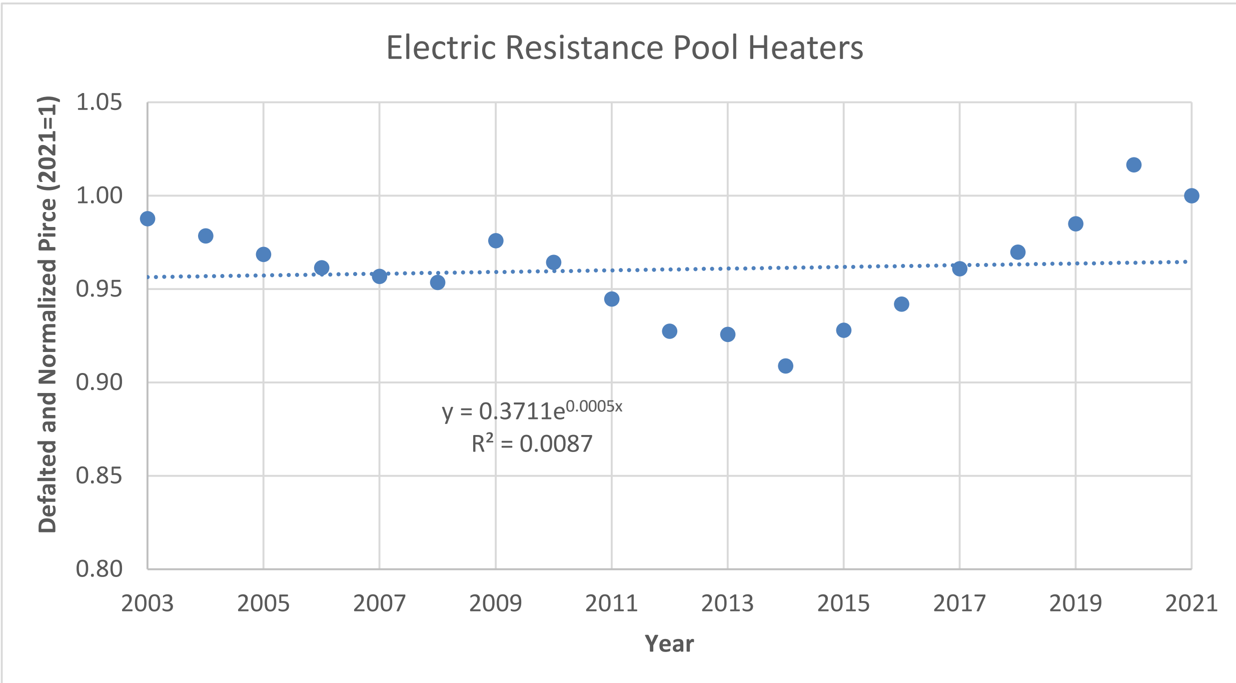

Figure 8C.3.2 Relative Price of Electric Resistance Pool Heaters versus Year, with Exponential Fit from 2003 to 2021

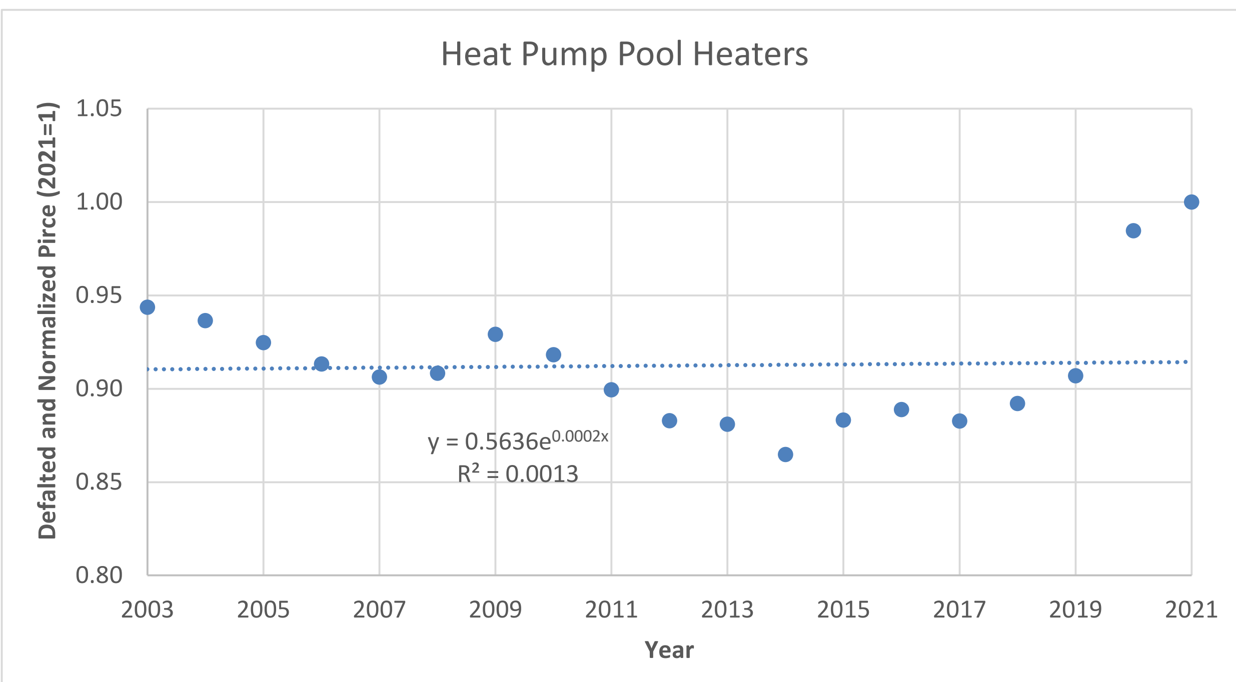

Figure 8C.3.3 Relative Price of Heat Pump Pool Heaters versus Year, with Exponential Fit from 2003 to 2021

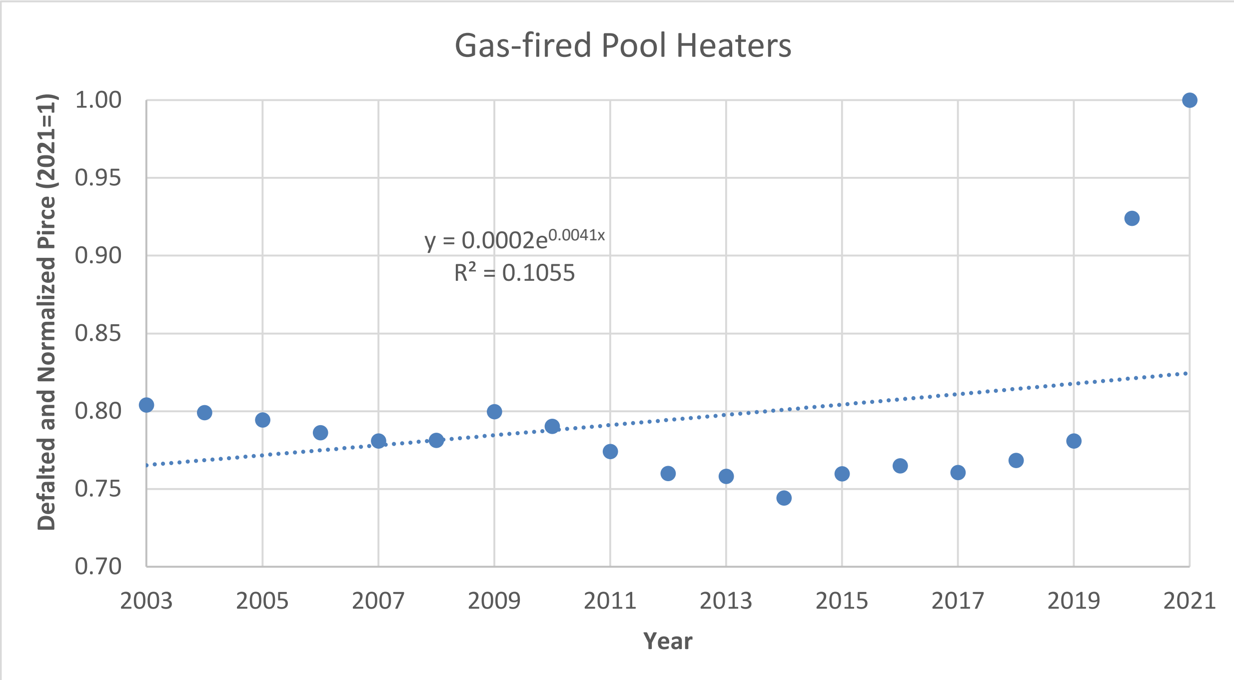

Figure 8C.3.4 Relative Price of Gas Pool Heaters versus Year, with Exponential Fit from 2003 to 2021

All three regressions performed as an exponential trend line fit result a moderate fit to the data. DOE then derived a price factor index, with 2021 equal to 1, to project prices in each future year in the analysis period considered in the NIA. The index value in a given year is a function of the exponential parameter and *year*. Based on this fitting, DOE used a constant trend as the reference, since for all pool heater designs there is a decreasing trend until 2014 and then a slight increasing trend from 2014 to 2019 and more pronounced increase for 2020 to 2021 likely due to COVID-19 pandemic and supply chain issues. The no price trend scenario assumes zero percent learning rate for all products, implying constant real prices over the entire forecast period.

8C.4 ALTERNATIVE POOL HEATER PRICE TREND SCENARIOS

DOE also investigated the impact of different product price trends on the life-cycle cost (LCC) results for the considered TSLs for pool heaters. DOE considered two alternative price trends for the sensitivity analysis. The high decreasing price trend scenario used the same exponential fit as the default scenario described in section 8C.2 to fit the historical distributor prices for EPHs, HPPHs, and GPHs at different ratings from the 2022 Pkdata,[1] during the period of 2003 to 2014 (decreasing trend) and 2014 to 2021 (increasing trend).

8C.4.1 Determination of Decreasing Price Trend Scenario

DOE examined the pool heaters data from 2003 to 2014, which demonstrates a downward trend than the full set of data. To estimate these exponential parameters for each product type, a least-square fit was performed on the inflation-adjusted pool heater prices versus *year* from 2003 to 2014 for ERPHs, HPPHs and GPHs separately (see Figure 8C.4.1 to Figure 8C.4.3).

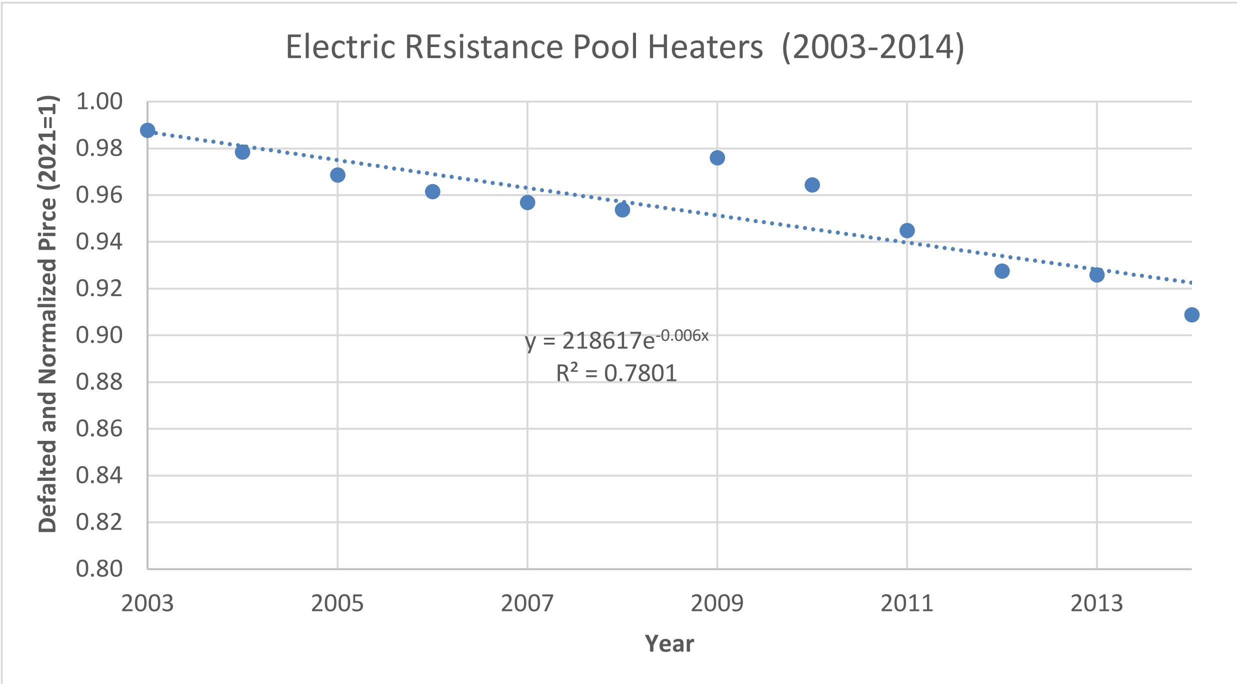

Figure 8C.4.1 Relative Price of Electric Resistance Pool Heaters versus Year, with Exponential Fit from 2003 to 2014

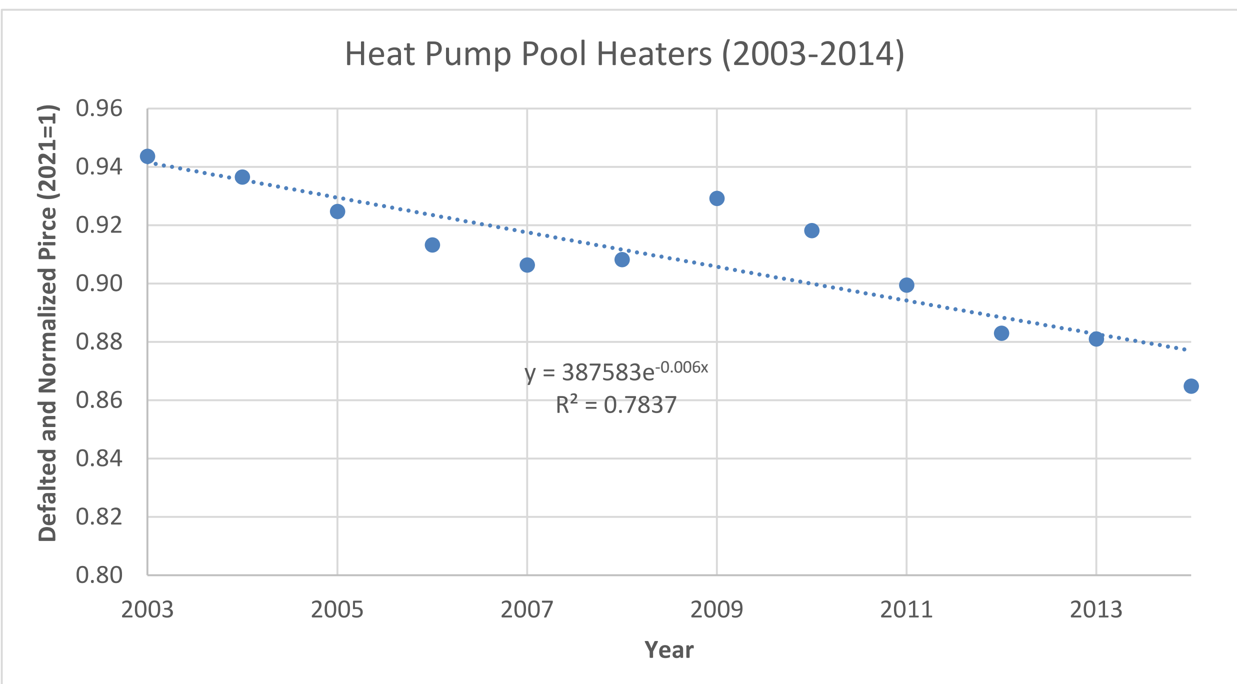

Figure 8C.4.2 Relative Price of Heat Pump Pool Heaters versus Year, with Exponential Fit from 2003 to 2014

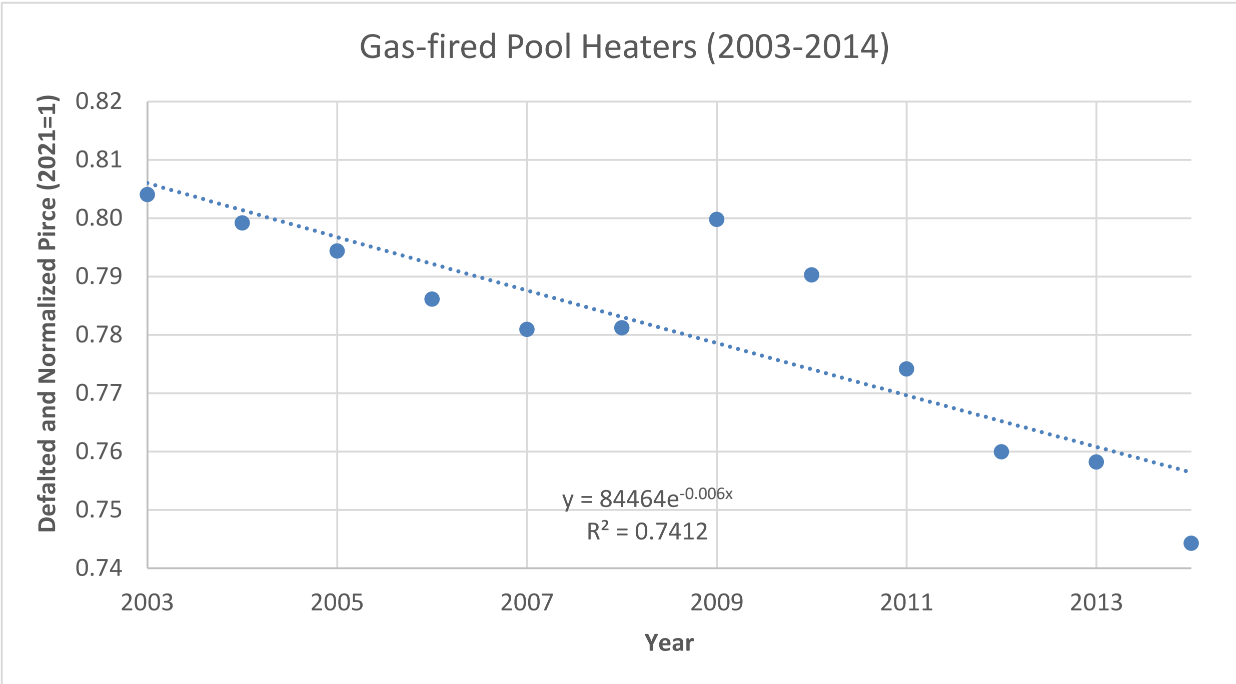

Figure 8C.4.3 Relative Price of Gas Pool Heaters versus Year, with Exponential Fit from 2003 to 2014

All three regressions performed as an exponential trend line fit result a moderate fit to the data. DOE then derived a price factor index, with 2021 equal to 1, to project prices in each future year in the analysis period considered in the NIA. The index value in a given year is a function of the exponential parameter and *year*. The resulting annual price decline rates are 0.61%, 0.64% and 0.58% for ERPHs, HPPHs, and GPHs, respectively.

The estimated price factor indices for ERPHs, HPPHs, and GPHs are shown in Figure 8C.4.4.

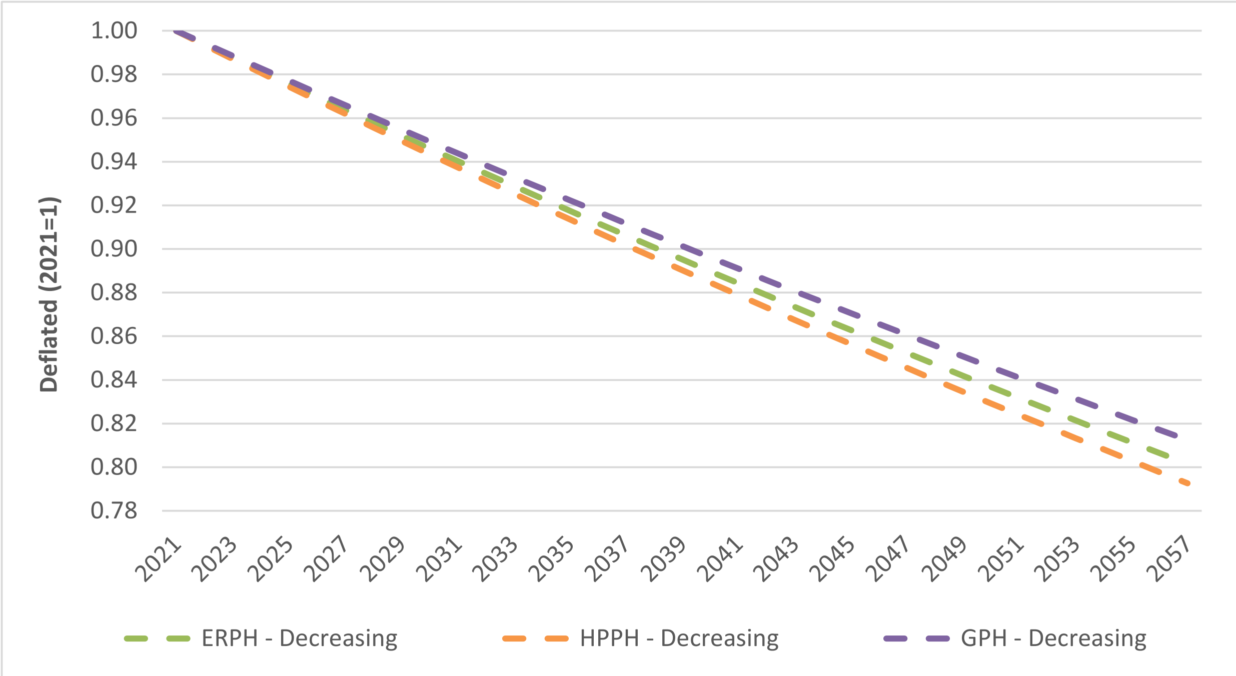

Figure 8C.4.4 Price Forecast Indices for Electric Resistance, Heat Pump, and Gas-fired Pool Heaters, Decreasing Trend

8C.4.2 Determination of Increasing Price Trend Scenario

DOE examined the pool heaters data from 2014 to 2019 and 2014 to 2021, which demonstrates a upward trend compared to the full set of data. To estimate these exponential parameters for each product type, a least-square fit was performed on the inflation-adjusted pool heater prices versus *year* from 2014 to 2021 for ERPHs, HPPHs, and GPHs separately (see Figure 8C.4.5 to Figure 8C.4.8).

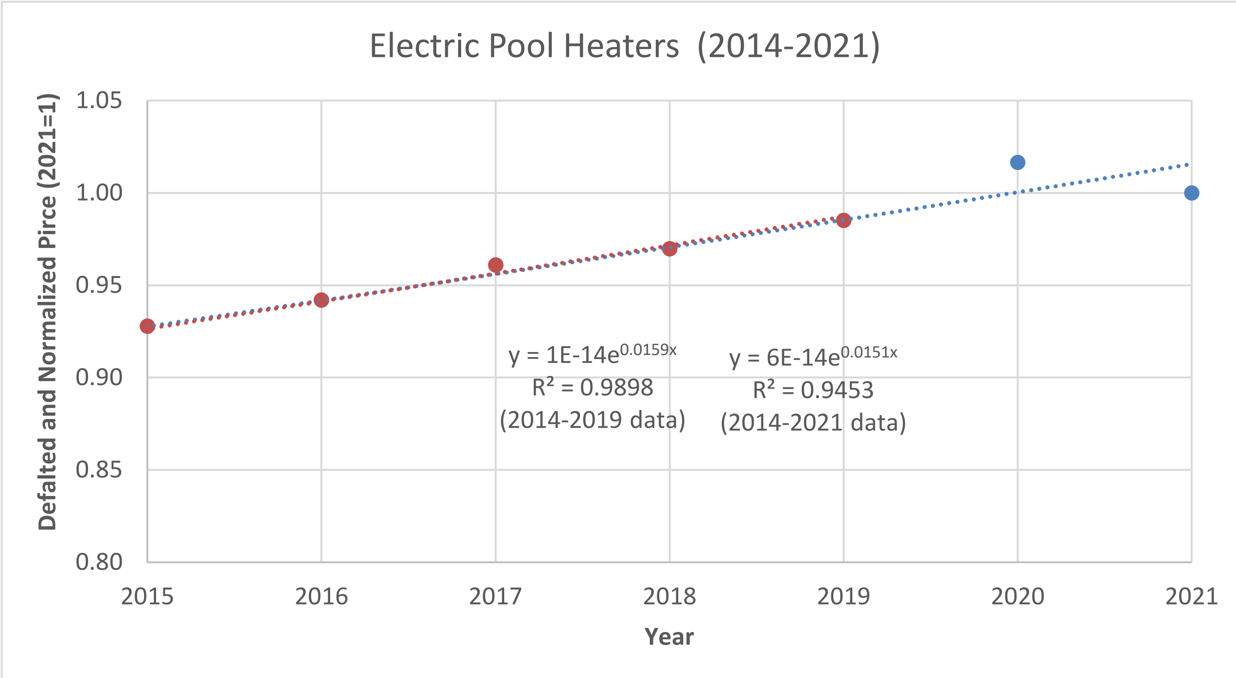

Figure 8C.4.5 Relative Price of Electric Resistance Pool Heaters versus Year, with Exponential Fit from 2014 to 2021

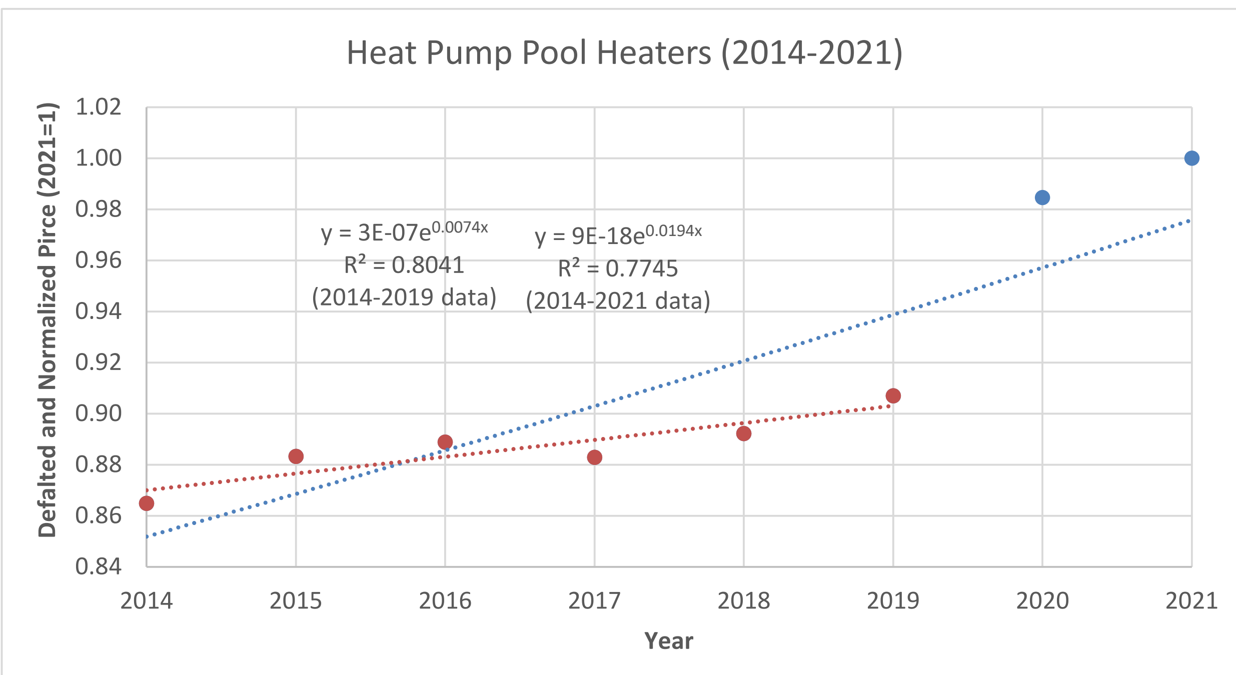

Figure 8C.4.6 Relative Price of Heat Pump Pool Heaters versus Year, with Exponential Fit from 2014 to 2021

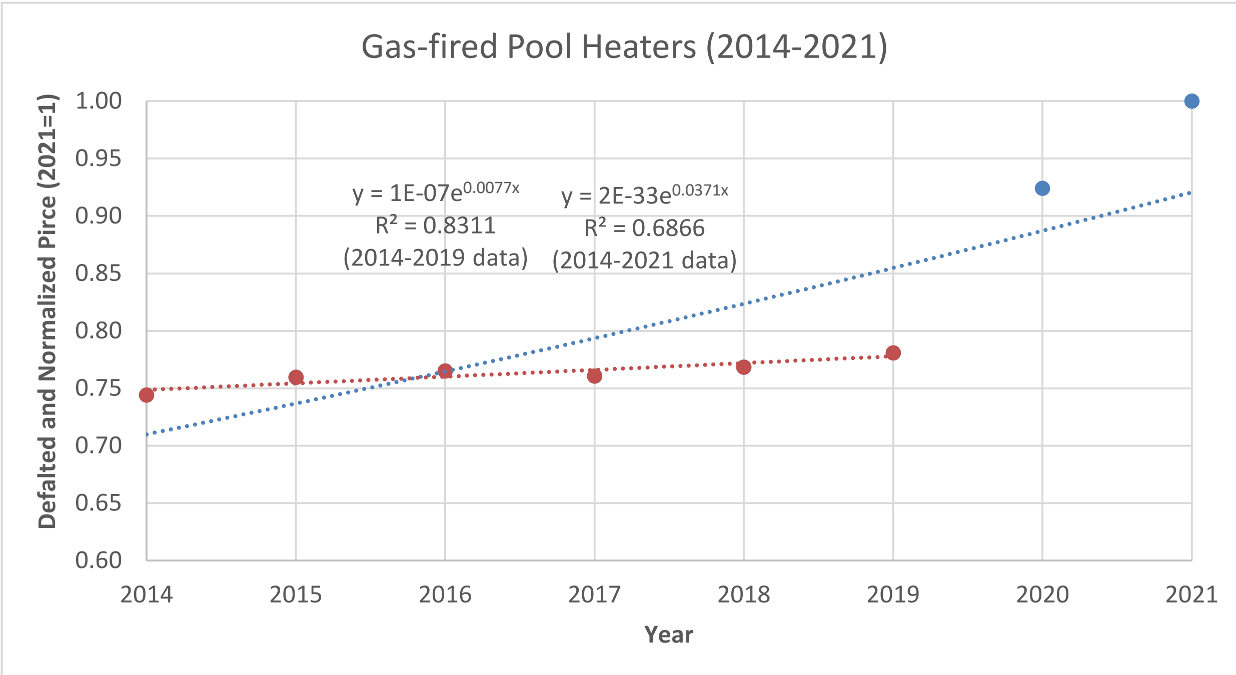

Figure 8C.4.7 Relative Price of Gas Pool Heaters versus Year, with Exponential Fit from 2014 to 2021

All three regressions performed as an exponential trend line fit result a moderate fit to the data. DOE then derived a price factor index, with 2021 equal to 1, to project prices in each future year in the analysis period considered in the NIA. The index value in a given year is a function of the exponential parameter and *year*. The resulting annual price increasing rates based on 2014-2019 data are 1.59%, 0.74% and 3.78% and based on 2014-2021 data are 1.52%, 1.96% and 3.78% for ERPHs, HPPHs, and GPHs, respectively. These fits though reflect data from 2020-2021 period impacted by COVID-19 pandemic and supply chain issues. DOE, therefore, chose to model an increasing price trend based on the mirror image of the decreasing price trend resulting annual price increasing rates are 0.61%, 0.64% and 0.58% for ERPHs, HPPHs, and GPHs, respectively. This is more similar to the 2014-2019 trends, except for ERPHs.

The estimated price factor indices for ERPHs, HPPHs, and GPHs are shown in Figure 8C.4.8.

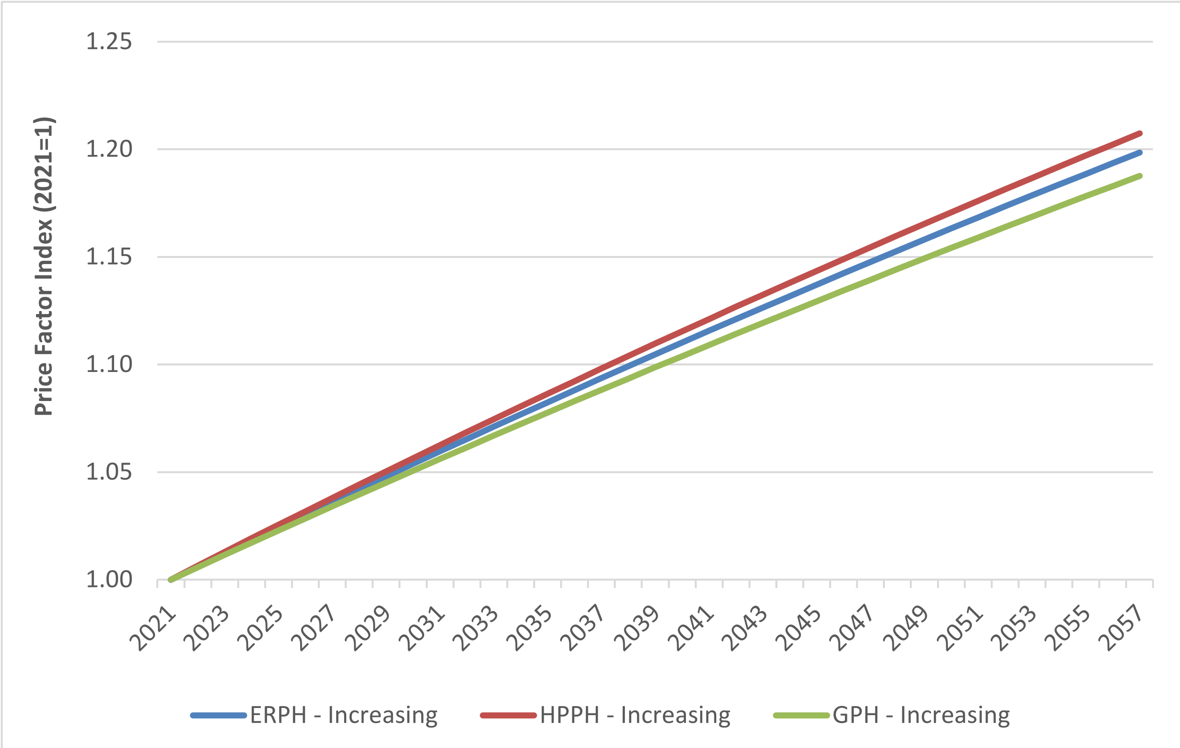

Figure 8C.4.8 Price Forecast Indices for Electric Resistance, Heat Pump, and Gas-fired Pool Heaters, Increasing Trend

8C.5 SUMMARY OF PRODUCT PRICE TRENDS FORECAST

Table 8C.5.1 and Figure 8C.5.1 shows the summary of the estimated learning rate in each price trend scenario used for ERPHs, HPPHs, and GPHs.

Table 8C.5.1 Price Trend Sensitivities

Sensitivity	Price Trend	Estimated Learning Rate %		
		ERPH	HPPH	GPH
Constant Price Trend Scenario	Constant price projection	0.00	0.00	0.00
Decreasing Price Trend Scenario	Exponential fit to the PKData from 2003 to 2014	0.61	0.64	0.58
Increasing Price Trend Scenario	Mirror image of Exponential fit to the PKData from 2003 to 2014	-0.61	-0.64	-0.58

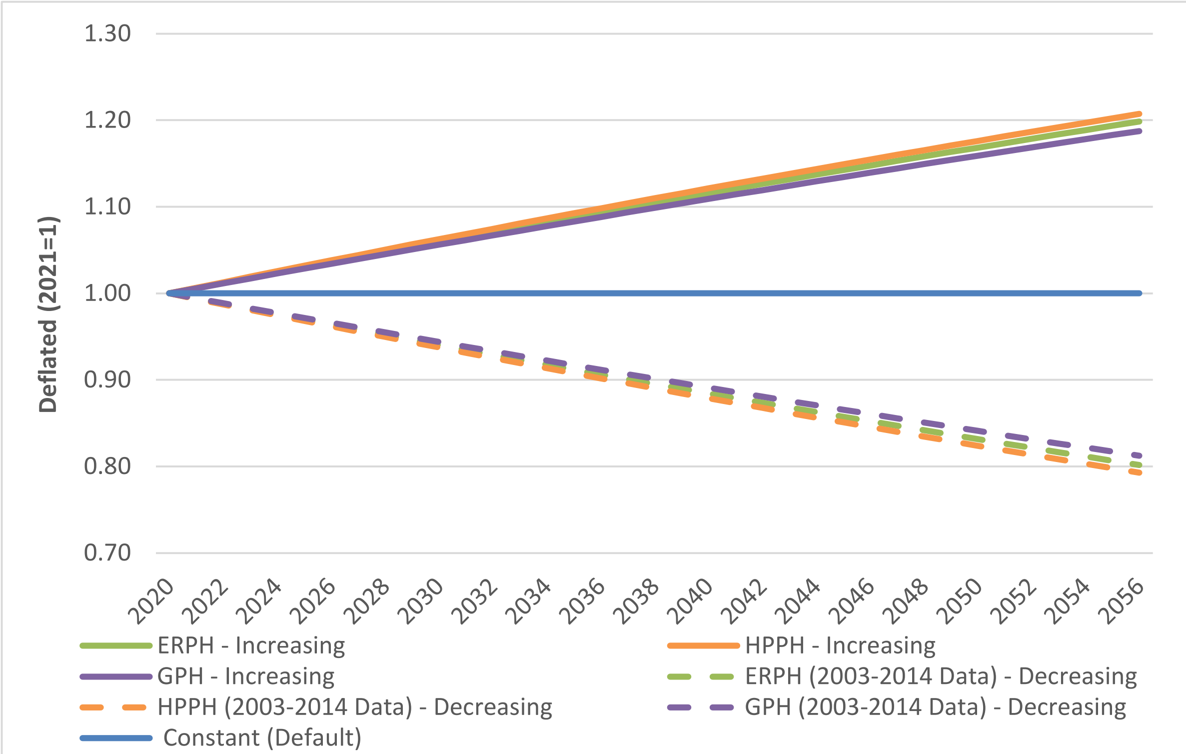

Figure 8C.5.1 Price Forecast Indices for Electric Resistance, Heat Pump, and Gas-fired Pool Heaters, Constant, Decreasing, and Increasing Trends

8C.6 PRODUCT PRICE TRENDS SENSITIVITIES

DOE produced results with a with a decreasing and increasing price trend. The results are presented in Table 8C.6.1 to Table 8C.6.6.

Table 8C.6.1 Decreasing Scenario LCC Results for Electric Pool Heaters

EL	TE_i (%)	All Consumers*					Impacted Consumers**	
		Installed Cost, 2021$	First Year Oper. Cost, 2021$	Lifetime Oper. Cost,* 2021$	LCC, 2021$	Simple PBP	LCC Saving, 2021$	Net Cost, %
0	99	3,557	2,006	16,897	20,454	NA	NA	NA
1	387	3,969	556	4,771	8,740	0.3	8,122	1
2	483	4,073	460	3,968	8,040	0.3	4,423	2
3	534	4,168	420	3,637	7,806	0.4	1,311	21
4	551	4,308	406	3,521	7,829	0.5	1,145	44
5	595	4,493	392	3,404	7,897	0.6	968	62

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.2 Decreasing Scenario LCC Results for Gas-fired Pool Heaters

EL	TE_i (%)	All Consumers*					Impacted Consumers**	
		Installed Cost, 2021$	First Year Oper. Cost, 2021$	Lifetime Oper. Cost,* 2021$	LCC, 2021$	Simple PBP	LCC Saving , 2021$	Net Cost, %
0	69.7	3,369	1,898	16,230	19,599	NA	NA	NA
1	81.3	3,382	1,819	15,462	18,843	0.2	784	0
2	83.3	3,616	1,785	15,182	18,799	2.2	90	39
3	94.7	4,515	1,617	13,805	18,320	4.1	535	72

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.3 Increasing Rate Scenario LCC Results for Electric Pool Heaters

EL	TE_i (%)	All Consumers*					Impacted Consumers**	
		Installed Cost, 2021$	First Year Oper. Cost, 2021$	Lifetime Oper. Cost,* 2021$	LCC, 2021$	Simple PBP	LCC Saving, 2021$	Net Cost, %
0	99	3,790	2,006	16,897	20,687	NA	NA	NA
1	387	4,266	556	4,771	9,037	0.3	8,059	1
2	483	4,379	460	3,968	8,347	0.4	4,384	3
3	534	4,484	420	3,637	8,121	0.4	1,293	23
4	551	4,636	406	3,521	8,157	0.5	1,116	47
5	595	4,839	392	3,404	8,242	0.6	925	64

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.4 Increasing Rate Scenario LCC Results for Gas-fired Pool Heaters

EL	TE_i (%)	All Consumers*					Impacted Consumers**	
		Installed Cost, 2021$	First Year Oper. Cost, 2021$	Lifetime Oper. Cost,* 2021$	LCC, 2021$	Simple PBP	LCC Saving, 2021$	Net Cost, %
0	69.7	3,562	1,898	16,230	19,792	NA	NA	NA
1	81.3	3,576	1,819	15,462	19,037	0.2	782	0
2	83.3	3,830	1,785	15,182	19,013	2.4	70	39
3	94.7	4,795	1,617	13,805	18,600	4.4	459	73

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.5 Product Price Trend Scenario Comparison of LCC, PBP and Net Cost Results for Electric Pool Heaters

EL	TE_i	Average LCC Savings 2021$			Simple Payback Period *years*			Net Cost *%*		
		Decr.	**Incr.**	**Ref. Case**	**Decr.**	**Incr.**	**Ref. Case**	**Decr.**	**Incr.**	**Ref. Case**
1	387	8,122	8,059	8,090	0.3	0.3	0.3	1	1	1
2	483	4,423	4,384	4,403	0.3	0.4	0.4	2	3	2
3	534	1,311	1,293	1,302	0.4	0.4	0.4	21	23	22
4	551	1,145	1,116	1,130	0.5	0.5	0.5	44	47	45
5	595	968	925	946	0.6	0.6	0.6	62	64	63

Table 8C.6.6 Product Price Trend Scenario Comparison of LCC, PBP and Net Cost Results for Gas-fired Pool Heaters

EL	TE_i	Average LCC Savings 2021$			Simple Payback Period *years*			Net Cost *%*		
		Decr.	**Incr.**	**Ref. Case**	**Decr.**	**Incr.**	**Ref. Case**	**Decr.**	**Incr.**	**Ref. Case**
1	81.3	784	782	783	0.2	0.2	0.2	0	0	0
2	83.3	90	70	80	2.2	2.4	2.3	39	39	39
3	94.7	535	459	497	4.1	4.4	4.2	72	73	73

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APPENDIX 8D. INSTALLATION COST DETERMINATION FOR POOL HEATERS

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APPENDIX 8D. INSTALLATION COST DETERMINATION FOR POOL HEATERS

8D.1 INTRODUCTION

This appendix provides details about the derivation of installation costs for pool heaters. The installation cost is the price to the consumer of labor and materials (other than the cost of the actual product) needed to install a pool heater.

The Department of Energy (DOE) estimated installation costs for pool heaters based on RSMeans, a well-known and respected construction cost estimation method, as well as manufacturer literature and information from expert consultants. Table 8D.1.1 offers an example of the installation cost calculation. All labor costs are derived using the latest residential 2021 RSMeans labor costs by crew type.[1] Replacement installation cost tables include a trip charge, which is often charged by contractors and estimated to be equal to one half hour of labor per crew member. Labor hours (or person-hours) are based on RSMeans data, expert data, or engineering judgment. Bare costs are all the costs without any markups. Material costs are based on RSMeans data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RSMeans. Values reported in this appendix are based on national average labor costs. In its analysis, DOE used regional labor costs to more accurately estimate installation costs by region. Section 8D.3 describes the derivation of regional labor costs. DOE then applied the appropriate regional labor cost to each RECS sample household.

Table 8D.1.1 Example of Installation Cost Calculation

Description	Crew	Labor Hours	Unit	Bare Costs *(2021$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	CREW1	0.5	-	0.00	23.00	23.00	1	35.00
Description of Installation Item	CREW1	0.5	Ea.	15.00	23.00	48.00	1	51.50
Total								**86.50**

The installation cost calculations for pool heaters encompass:

- new pool construction, new pool heater owner, and replacement markets;
- residential and commercial markets; and
- outdoor and indoor installations.

8D.2 POOL HEATER INSTALLATION COST METHODOLOGY

8D.2.1 Overview

DOE developed installation costs for pool heaters using RSMeans cost data[1] and the 2010 heating products final rule technical support document.[2] The installation cost is divided into the following three components:[a]

- Setting up new pool heater and removal of old pool heater
- Installing a water piping connection, and
- Installing gas piping or an electrical connection.

The following information about market shares, technologies, and installation location helped to shape the installation cost calculations.

New Swimming Pool Owner, New Pool Heater Owner with Existing Pools, and Replacement Market Shares. As determined in the shipments analysis (see chapter 9), approximately 37 percent of the market will be new swimming pool owners, 3 percent will be new pool heater owners with existing swimming pools, and 61 percent will be replacements in 2028.

Electric Pool Heater Technologies. There are two main electric pool heater designs: electric resistance and heat pump. Almost all of the electric resistance models have an integrated thermal efficiency of 99 percent, which represents the analysis baseline. Heat pump pool heaters generally have an integrated thermal efficiency of 360 percent or greater.

Gas-fired Pool Heater Technologies. There are two main gas-fired pool heater designs: non-condensing and condensing. Typically, gas-fired pool heaters with a thermal efficiency of 90 percent or less are non-condensing, while those with a thermal efficiency of greater than 90 percent are condensing.

Installation Locations. For gas-fired pool heaters, DOE assumed that most pool heaters will be installed outdoors. It is more common for the pool equipment to be indoors if the swimming pool and spa are indoors. For residential installations, DOE assumed that only about 1 percent are installed indoors with an indoor swimming pool or spa. For commercial installation, DOE assumed that about one third are installed indoors with an indoor swimming pool or spa.

8D.2.2 New Pool Heaters

DOE estimated basic installation costs that are applicable to new gas-fired and electric pool heaters installed in either new swimming pools or existing swimming pools without a pool heater. For setting up, connecting, and starting up the new pool heater, DOE assumed 10 hours of

[a] DOE assumed that heat pump pool heater condensate removal is not an installation issue because the pool heater is installed on a concrete slab and condensation drains through holes from the bottom of the unit.[3]

labor. For water piping, DOE assumed 10 feet of 1” PVC piping based on RSMeans and consultant input.[1,4] These costs apply to all pool heaters. DOE assumed that natural gas-fired pool heaters would need 10 feet of 1” of threaded Schedule 40 gas piping with couplings and clevis type hangars. For gas-fired pool heaters fueled by propane, DOE assumed that 10 feet of 4” PVC would be needed. DOE assumed that electric resistance pool heaters would need a 100 amp circuit (for the 30 kW required) and applied the electrical connection cost of installing an air source space heating/cooling heat pump from RSMeans. DOE assumed that heat pump pool heaters need a smaller 20 to 30 amp circuit similar and applies an electrical connection cost of installing an air conditioner in RSMeans data. For gas-fired pool heater, DOE assumed that it would need a regular 120V outlet. For heat pump water heaters and for condensing gas-fired water heaters the cost of condensate withdrawal is added. Any installation costs associated with flue venting were also taken into account for gas-fired pool heaters.

Table 8D.2.1 New Pool Heater Installation Cost Summary for Electric Pool Heaters

Pool Heater Type	**Installation Cost Item Description**	**Material Cost** (2021$)*	**Total Labor Hours**	**Average National Cost** (2021$)
Basic Installation Costs (Setting up, connecting start-up (including water piping))				
All Electric Pool Heaters	Setting up, connecting start-up (including water piping)	$50	10	$928
Electrical Connection (Outdoors)				
ERPH (EL 0)	100 amp, 2 pole, EMT & wire, 100 ft	$543	9.011	$1,453
HPPH (All)	30 amp, EMT & wire, 100 ft	$182	6.654	$810
Electrical Connection (Indoors)				
ERPH (EL 0)	100 amp, 2 pole, Type NM cable for indoor, 100 ft	$416	6.654	$1,090
HPPH (All)	30 amp, Type NM cable for indoor, 100 ft	$146	2.786	$423
Condensate Withdrawal				
HPWH (Only)	10 ft of pipe towards a drain	$1.03/ft	---	$12

*Does not include sales tax or markups by trade from RSMeans.

Table 8D.2.2 New Pool Heater Installation Cost Summary for Gas-fired Pool Heaters

Pool Heater Type	Installation Cost Item Description	Material Cost (2021$)*	Total Labor Hours	Average National Cost (2021$)
Basic Installation Costs (Setting up, connecting start-up (including water piping))				
All Gas-fired Pool Heaters	Setting up, connecting start-up (including water piping)	$50	10	$731
All Natural Gas Pool Heaters	100 ft of gas piping for natural gas	$3.37/ft	0.074/ft	$1,151
All Propone Pool Heaters	10 ft of gas piping for natural gas	$3.37/ft	0.074/ft	$303
Flue Venting (Outdoors)				
Atmospheric GPH (if required)	Drafthood (5 Ft vent chimney stack, Top)	$13.55/ft $23.97/ea	0.267/ft 0.400/ea	$220
Flue Venting (Indoors)				
Atmospheric GPH	6” diameter Type B flue vent pipe	multiple components		$765
Induced draft GPH	4” diameter Type B flue vent pipe	multiple components		$618
Condensing GPH (Only)	PVC venting	multiple components		$336
Condensate Withdrawal				
Condensing GPH (Only)	10 ft of pipe towards a drain	$2.98/ft	0.081	$89

*Does not include sales tax or markups by trade from RSMeans.
Note that assumption is that electrical connection is available for the pool heater on site as part of the overall construction of the pool.

8D.2.3 Replacement Pool Heaters

DOE also estimated basic installation costs for replacement pool heater installations. For all outdoor installations, based on RSMeans and consultant input, DOE assumed 16.5 labor hours for EPHs and GPH, which includes a trip charge, setting up, connecting, start-up, water piping connection, gas-piping, electrical connection, and removal of the old pool heater.[1,4] These costs apply to all pool heaters. DOE assumed that most electric pool heaters installed indoors are electric resistance pool heaters. DOE assumed that the replacement installation cost of indoor electric resistance pool heaters is the same as for outdoor units. Installing a heat pump pool heater indoors would require significant installation cost to bring the water piping and electrical connections from an outdoor installation location of the heat pump pool heater to the indoors swimming pool.

Table 8D.2.3 Replacement Pool Heater Installation Cost Summary for Electric Pool Heaters

Pool Heater Type	Installation Cost Item Description	Material Cost (2021$)*	Total Labor Hours**	Average National Cost (2021$)
Basic Installation Costs (Setting up, connecting start-up (including water piping))				
All Electric Pool Heaters	Setting up, connecting start-up (including water piping)	$50	16.5	$746
Water Piping and Electrical Connection when switching from ERPH to HPPH (Indoors)				
HPPH (if replacing an ERPH installed indoors)	Costs associated with extending the water piping and electrical connections.	Multiple components		$1,335
Condensate Withdrawal				
HPWH (Only)	10 ft of pipe towards a drain	$1.03/ft	---	$12

*Does not include sales tax or markups by trade from RS Means.
** Includes trip charge (0.5 hours).

Table 8D.2.4 Replacement Pool Heater Installation Cost Summary for Gas-fired Pool Heaters

Pool Heater Type	Installation Cost Item Description	Material Cost (2021$)*	Total Labor Hours**	Average National Cost (2021$)
Basic Installation Costs (Setting up, connecting start-up (including water piping))				
All Gas-fired Pool Heaters	Setting up, connecting start-up (including water piping)	$50	16.5	$618
Flue Venting (Outdoors)				
Atmospheric GPH (if required)	Drafthood (5 Ft vent chimney stack, Top)	$13.55/ft $23.97/ea	.267/ft .4/ea	$220
Condensate Withdrawal				
Condensing GPH (Only)	10 ft of pipe towards a drain	$3.37/ft	0.081	$89

*Does not include sales tax or markups by trade from RS Means.
** Includes trip charge (0.5 hours).

8D.3 RSMEANS 2021 Regional Labor Costs

DOE used regional material and labor costs to more accurately estimate installation costs by region. RSMeans provides average national labor costs for different trade groups as shown in Table 8D.3.1. Bare costs are given in RS Means, and overhead and profit (O&P) labor costs are the bare costs multiplied by the RS Means markups.

Table 8D.3.1 RSMeans 2021 National Average Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour (2021$)	
			Bare Costs	**Incl. O&P***
Residential Labors Costs				
Q19	1 Steamfitter 1 Steamfitter Apprentice 1 Electrician	3	$40.07	$65.32
Q6	1 Steamfitters 2 Steamfitter Apprentices	3	$37.32	$60.92
Standard Union Costs				
Q19	1 Steamfitter 1 Steamfitter Apprentice 1 Electrician	3	$62.25	$92.77
Q6	2 Steamfitters 1 Steamfitter Apprentice	3	$63.80	$95.22

* O&P includes markups provided in RSMeans.

RSMeans also provides material and labor cost factors for 295 cities and towns in the U.S. To derive average labor cost values by state, DOE weighted the material and labor cost factors by swimming pools and spas by state using 2022 Pkdata.[6] DOE used the material and labor cost factors for cost associated with fire suppression, plumbing, and HVAC. Table 8D.3.2 shows the final regional material and labor price factors used in the analysis by state.

Table 8D.3.2 Material and Labor Cost Factors by State

State	Plumbing, HVAC		Electrical		Weighted Average	
	Material	Labor	Material	Labor	Material	Labor
Alabama	1.01	0.63	0.98	0.66	0.98	0.70
Alaska	1.01	1.04	1.16	1.08	1.20	1.10
Arizona	0.99	0.76	0.97	0.63	0.98	0.72
Arkansas	1.00	0.52	0.97	0.58	0.95	0.64
California	1.00	1.39	0.99	1.33	1.00	1.34
Colorado	1.01	0.72	1.01	0.75	1.03	0.73
Connecticut	1.01	1.19	0.94	1.13	1.01	1.18
Delaware	1.01	0.89	0.96	1.04	1.01	0.88
District of Columbia	1.00	1.21	0.98	1.10	0.99	1.11
Florida	0.99	0.63	0.97	0.64	0.98	0.68
Georgia	1.00	0.68	0.98	0.68	0.97	0.73
Hawaii	1.01	1.09	1.07	1.22	1.19	1.18
Idaho	1.01	0.75	0.93	0.71	1.02	0.79
Illinois	1.00	1.29	0.96	1.29	0.99	1.37
Indiana	1.00	0.78	0.99	0.85	0.98	0.82
Iowa	1.00	0.82	0.99	0.79	0.97	0.85
Kansas	1.00	0.76	0.99	0.76	0.96	0.78
Kentucky	1.00	0.78	0.94	0.76	0.95	0.79
Louisiana	1.01	0.62	1.00	0.65	0.97	0.67
Maine	1.00	0.75	1.00	0.75	0.99	0.85
Maryland	1.00	0.81	0.96	0.88	1.01	0.83
Massachusetts	0.99	1.15	0.99	1.16	0.99	1.24
Michigan	1.00	0.93	0.99	0.95	0.98	0.94
Minnesota	1.00	1.10	1.03	1.12	0.99	1.13
Mississippi	1.01	0.56	1.00	0.54	0.98	0.64
Missouri	1.00	0.96	1.00	0.90	0.97	0.96
Montana	1.00	0.71	1.01	0.71	1.01	0.76
Nebraska	1.00	0.81	1.02	0.76	0.99	0.80
Nevada	1.01	0.96	1.01	1.04	1.04	1.00
New Hampshire	1.01	0.84	0.96	0.76	0.99	0.91
New Jersey	1.01	1.33	0.98	1.40	0.99	1.35
New Mexico	1.01	0.68	0.88	0.71	0.99	0.71
New York	1.00	1.68	0.99	1.78	1.00	1.68
North Carolina	1.01	0.60	0.99	0.65	0.99	0.67
North Dakota	1.00	0.73	0.99	0.70	0.99	0.80
Ohio	1.00	0.86	1.00	0.83	0.99	0.83
Oklahoma	1.01	0.64	1.00	0.70	0.97	0.66
Oregon	1.01	1.10	0.98	1.02	1.02	1.03
Pennsylvania	0.97	1.19	0.97	1.32	0.98	1.19
Rhode Island	1.01	1.11	1.02	0.98	1.01	1.13
South Carolina	1.01	0.56	0.98	0.67	0.98	0.68
South Dakota	1.00	0.68	1.01	0.60	0.99	0.76
Tennessee	1.01	0.73	1.00	0.64	0.98	0.71
Texas	1.00	0.60	1.00	0.59	1.00	0.64
Utah	1.01	0.74	0.96	0.70	1.02	0.74
Vermont	0.99	0.71	1.04	0.58	1.00	0.84
Virginia	1.01	0.76	0.95	0.78	1.00	0.74
Washington	1.01	1.08	1.02	1.06	1.05	1.03
West Virginia	1.00	0.89	0.96	0.86	0.98	0.90
Wisconsin	0.98	1.04	0.99	1.00	0.98	1.06

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APPENDIX 8E. ENERGY PRICE CALCULATIONS FOR POOL HEATERS

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APPENDIX 8E. ENERGY PRICE CALCULATIONS FOR POOL HEATERS

8E.1 INTRODUCTION

Figure 8E.1.1 depicts the energy price calculation process, which also encompasses average energy price, seasonal marginal price factor, and monthly price factor calculations.

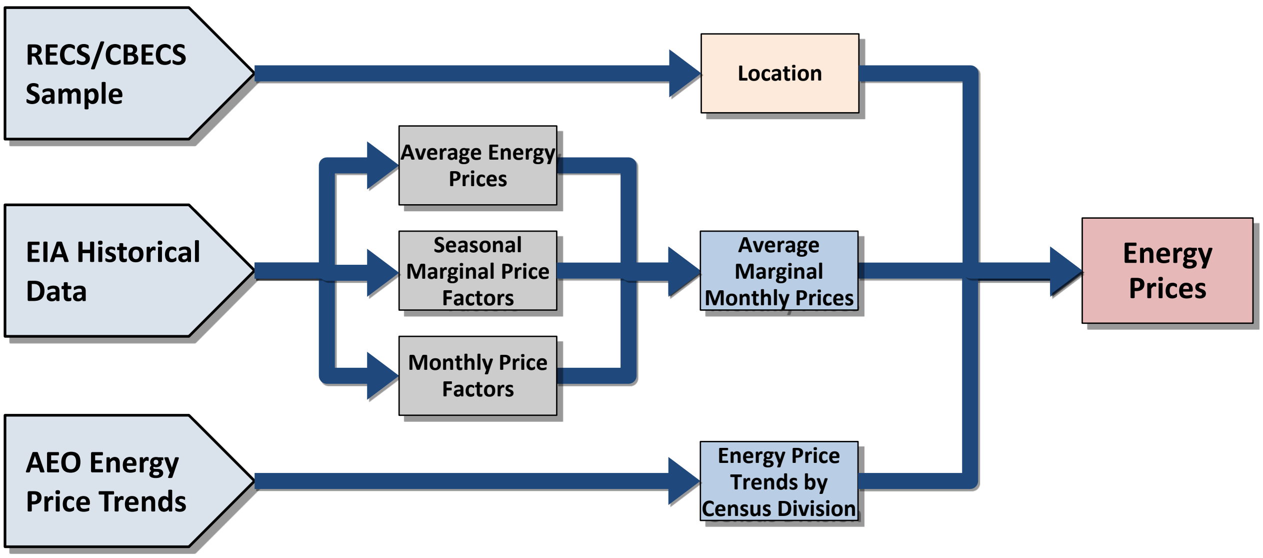

Figure 8E.1.1 Energy Price Calculation Process

DOE used Energy Information Administration (EIA) data by state to determine average annual prices for the 2021 base year (section 8E.2), monthly price factors (section 8E.3), and seasonal marginal price factors (section 8E.4). To match the state energy price data to the building sample developed using EIA's *2015 Residential Energy Consumption Survey* (RECS 2015)[1] and *2012 Commercial Building Energy Consumption Survey* (CBECS 2012),[2] the Department of Energy (DOE) used weather data to assign a state to each sampled housing unit or building (see appendix 7E for more details).

Energy prices were then escalated by the EIA's *2022 Annual Energy Outlook* (AEO 2022)[3] forecasts to estimate future energy prices at the census division level (see section 8E.7).

8E.2 AVERAGE ANNUAL ENERGY PRICE DETERMINATION

8E.2.1 Annual Electricity and Natural Gas Prices

DOE derived 2021 annual electricity prices from EIA's Form 861M.[4] The EIA Form 861M data include residential and commercial energy prices by state. Table 8E.2.1 and Table 8E.2.2 show the monthly residential and commercial electricity prices for each state. DOE calculated annual electricity prices by averaging monthly electricity prices by state.

DOE obtained the data for natural gas prices from EIA's Natural Gas Navigator,[5] which includes monthly natural gas prices by state for residential, commercial, and industrial customers. Table 8E.2.3 shows the monthly residential natural gas prices for each state. Table 8E.2.4 shows the monthly commercial natural gas prices for each state. DOE calculated both residential and commercial annual natural gas prices by averaging monthly natural gas prices by state. DOE used a conversion factor (1.037) to convert cubic feet of natural gas to MMBtu.[a]

[a] www.eia.gov/tools/faqs/faq.cfm?id=45&t=7

Table 8E.2.1 2021 Monthly Residential Electricity Prices by State (2021¢/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	12.38	12.99	13.35	13.73	13.54	13.52	13.35	13.53	13.60	13.81	13.41	9.79	13.08
Alaska	21.45	21.76	22.03	22.30	23.05	23.61	23.42	23.31	23.21	23.21	22.60	22.17	22.68
Arizona	11.70	12.10	12.18	12.54	13.05	12.66	12.64	12.59	12.75	12.83	12.31	12.63	12.50
Arkansas	9.42	13.99	10.27	10.95	11.17	11.32	11.42	11.49	11.66	11.47	11.53	10.86	11.30
California	21.43	22.53	22.71	23.37	22.75	23.11	22.46	23.35	23.44	22.00	23.76	23.22	22.85
Colorado	12.14	12.61	12.33	12.53	12.61	13.13	13.44	13.56	13.87	13.79	13.81	13.51	13.11
Connecticut	21.29	22.69	22.74	23.72	22.08	20.76	22.04	20.75	22.42	22.85	21.35	20.85	21.96
Delaware	11.78	12.00	12.11	12.74	13.41	12.44	11.88	12.19	13.26	13.69	13.91	12.62	12.67
District of Columbia	12.26	12.79	12.91	13.35	13.40	13.00	12.91	13.11	13.08	13.86	14.11	13.39	13.18
Florida	11.65	11.92	11.65	11.77	11.84	11.98	11.89	11.97	12.45	12.21	12.60	12.20	12.01
Georgia	10.94	11.67	11.83	12.23	13.25	13.61	13.55	13.37	12.97	12.93	12.34	12.15	12.57
Hawaii	30.55	32.35	32.96	32.79	32.80	32.74	33.23	33.14	34.30	34.28	33.97	35.57	33.22
Idaho	10.05	9.62	9.99	9.65	10.35	9.95	10.41	10.74	10.42	10.60	10.22	10.33	10.19
Illinois	12.31	12.27	13.88	14.04	14.25	12.89	12.74	12.89	13.09	13.98	14.39	13.53	13.35
Indiana	12.26	12.39	13.17	13.94	14.21	13.73	13.43	13.43	13.65	14.31	14.36	13.65	13.54
Iowa	10.88	11.62	11.30	12.35	13.39	14.00	14.39	14.59	13.87	12.53	12.28	11.55	12.73
Kansas	11.86	12.15	12.85	13.60	13.78	13.27	13.07	13.07	12.85	13.12	13.30	12.69	12.97
Kentucky	10.47	10.32	11.03	12.09	11.86	11.47	11.60	11.63	11.78	12.26	12.49	12.19	11.60
Louisiana	9.58	9.99	10.15	11.03	11.68	11.36	10.91	11.49	11.70	11.70	11.67	11.56	11.07
Maine	16.50	16.24	16.42	16.46	16.62	16.58	16.38	17.14	17.99	18.18	18.21	17.91	17.05
Maryland	12.62	12.46	12.84	12.99	12.90	13.08	12.98	12.91	13.30	14.48	13.66	14.08	13.19
Massachusetts	22.32	22.65	23.29	23.51	22.82	22.29	22.89	22.24	23.48	22.59	23.32	24.30	22.98
Michigan	16.92	16.95	17.17	17.58	17.69	17.84	17.79	17.86	17.63	17.96	17.62	17.25	17.52
Minnesota	12.48	12.61	12.89	13.17	13.55	14.09	13.98	13.93	14.21	14.03	13.60	12.80	13.45
Mississippi	10.88	11.34	11.52	12.13	12.42	11.94	11.65	11.67	11.61	11.96	12.39	11.98	11.79
Missouri	9.39	9.36	10.37	11.16	11.46	13.28	13.21	13.21	13.11	11.26	11.02	10.62	11.45
Montana	10.72	10.68	10.93	11.08	11.31	11.53	11.56	11.63	11.84	11.73	11.42	11.14	11.30
Nebraska	9.41	9.41	10.13	11.62	11.37	11.35	11.63	11.64	11.78	11.46	10.97	10.22	10.91
Nevada	11.53	11.84	11.96	12.18	11.14	11.22	10.86	10.99	11.22	12.58	12.67	12.21	11.70
New Hampshire	18.93	19.27	19.23	19.82	19.96	19.27	19.05	19.59	20.67	21.06	21.17	21.02	19.92
New Jersey	16.19	16.38	15.64	16.55	16.02	16.43	16.99	16.78	16.34	16.20	16.16	16.00	16.31
New Mexico	12.53	12.93	12.74	13.09	13.30	13.98	14.49	14.53	14.64	13.74	13.60	13.07	13.55
New York	18.27	18.78	18.04	18.52	19.89	19.56	19.60	19.92	20.46	20.59	20.04	19.50	19.43
North Carolina	10.60	11.13	11.45	11.67	11.83	11.51	11.56	11.54	12.02	12.29	11.60	11.29	11.54
North Dakota	9.46	9.46	10.18	10.80	11.94	12.21	12.23	11.97	12.81	11.61	10.91	9.35	11.08
Ohio	11.85	11.67	12.43	13.19	13.04	13.35	13.14	13.09	13.12	13.24	13.02	12.78	12.83
Oklahoma	8.93	24.75	8.90	11.46	10.93	10.07	11.23	11.43	12.07	12.95	11.69	10.73	12.10
Oregon	11.01	10.95	11.10	11.33	11.59	11.47	11.49	11.52	11.67	11.73	11.41	11.16	11.37
Pennsylvania	13.09	13.08	13.25	13.76	13.89	14.02	13.73	13.89	14.10	14.53	14.17	14.37	13.82
Rhode Island	23.41	24.09	23.35	23.54	20.80	19.74	20.50	20.35	23.35	22.39	22.84	25.11	22.46
South Carolina	11.99	12.92	13.28	13.29	13.19	13.24	12.90	13.17	13.74	13.81	14.09	13.07	13.23
South Dakota	10.99	12.31	11.30	11.96	13.12	12.94	12.85	12.83	13.16	12.70	12.00	11.53	12.31
Tennessee	10.38	10.30	10.73	11.60	11.53	11.46	11.26	11.23	11.25	11.50	11.70	11.64	11.21
Texas	11.40	12.74	11.50	11.91	11.94	12.01	11.70	11.98	12.24	12.56	12.81	12.55	12.11
Utah	10.04	10.05	10.06	10.07	10.12	10.83	11.00	11.01	10.98	10.52	10.26	10.16	10.42
Vermont	18.39	18.40	18.75	19.48	19.60	19.36	18.99	19.12	19.56	20.55	20.15	19.60	19.33
Virginia	11.05	11.39	11.71	12.87	12.25	12.59	12.71	12.92	12.55	12.58	11.97	11.85	12.20
Washington	9.75	9.79	9.96	10.12	10.20	10.13	10.24	10.27	10.40	10.38	10.22	10.07	10.13
West Virginia	11.20	11.11	12.49	12.43	12.56	12.22	12.11	12.22	12.71	13.67	12.89	11.82	12.29
Wisconsin	14.05	13.99	14.35	14.62	15.31	14.69	14.56	14.46	15.07	15.12	14.84	14.22	14.61
Wyoming	10.46	10.86	10.79	11.11	11.44	12.07	11.72	11.65	12.05	11.69	10.97	10.63	11.29
United States	12.69	13.35	13.3	13.76	13.89	13.85	13.87	13.97	14.19	14.11	14.12	13.75	13.74

Table 8E.2.2 2021 Monthly Commercial Electricity Prices by State (2021¢/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	11.77	12.60	12.21	12.28	12.17	12.29	12.26	12.30	12.11	12.45	12.59	9.05	12.01
Alaska	18.66	19.25	19.22	19.35	20.45	20.29	19.97	19.63	19.52	19.88	19.86	19.21	19.61
Arizona	9.34	9.41	9.60	9.96	10.75	10.81	11.13	10.69	10.66	10.20	9.88	10.06	10.21
Arkansas	8.40	13.05	9.05	8.73	8.98	9.12	9.52	9.56	9.50	10.06	8.82	9.06	9.49
California	16.52	17.54	17.19	18.70	17.73	20.24	20.88	21.31	21.81	20.28	17.60	18.44	19.02
Colorado	9.70	10.52	10.02	10.35	10.47	11.64	11.73	11.61	11.44	10.91	10.87	10.54	10.82
Connecticut	16.45	17.30	17.06	16.90	16.16	16.32	17.65	14.87	17.94	16.77	16.79	16.83	16.75
Delaware	9.05	9.55	9.57	9.09	9.49	9.48	9.37	9.44	9.96	9.60	10.18	9.76	9.55
District of Columbia	11.67	12.67	12.19	12.09	12.66	12.44	12.89	13.73	12.89	13.94	14.50	14.10	12.98
Florida	9.35	9.76	9.35	9.34	9.41	9.41	9.31	9.33	9.70	9.68	10.25	9.83	9.56
Georgia	9.96	10.93	10.21	10.40	10.52	10.68	10.97	10.98	10.91	11.51	11.47	10.88	10.78
Hawaii	29.30	30.69	30.76	30.17	30.05	30.19	30.99	30.96	31.76	31.92	32.36	34.45	31.13
Idaho	7.60	7.49	7.76	7.73	7.78	8.44	7.99	8.28	7.83	8.13	7.92	7.72	7.89
Illinois	8.95	9.39	9.82	9.62	9.68	9.45	9.40	9.58	9.90	10.41	10.39	9.84	9.70
Indiana	11.14	11.45	11.64	11.54	11.76	11.53	11.43	11.58	11.72	11.75	12.06	11.97	11.63
Iowa	8.98	9.70	8.99	9.18	10.21	11.31	11.67	11.83	11.31	9.49	9.55	9.25	10.12
Kansas	9.81	10.21	10.48	10.63	10.73	10.80	10.76	10.70	10.49	10.43	10.49	10.27	10.49
Kentucky	10.12	10.26	10.70	10.83	10.83	10.46	10.74	10.64	11.23	10.94	11.32	11.55	10.80
Louisiana	9.49	9.89	9.98	10.15	10.47	10.21	9.72	10.25	10.57	10.68	11.06	10.95	10.29
Maine	12.81	12.91	12.58	12.34	12.58	12.45	12.49	12.75	12.98	13.82	13.92	13.85	12.96
Maryland	9.90	10.18	10.05	9.89	9.97	10.01	9.94	10.08	10.25	10.70	10.83	11.48	10.27
Massachusetts	16.29	16.84	16.83	15.85	16.19	16.95	17.94	17.93	18.01	17.60	17.16	17.87	17.12
Michigan	11.96	12.21	12.21	12.22	12.53	12.37	12.19	12.30	12.24	12.30	12.51	12.21	12.27
Minnesota	9.69	10.09	10.12	10.81	11.21	12.57	11.97	11.78	11.89	11.38	11.32	10.65	11.12
Mississippi	10.70	11.39	11.16	11.04	11.13	10.93	10.73	10.82	10.77	11.08	11.52	11.33	11.05
Missouri	7.69	7.94	8.33	8.41	8.60	10.79	10.72	10.74	10.45	8.53	8.66	8.49	9.11
Montana	10.39	10.40	10.59	10.42	10.66	10.82	10.57	10.62	10.71	10.86	10.86	10.55	10.62
Nebraska	8.44	8.34	8.68	8.77	8.87	9.28	9.41	9.18	9.15	8.75	8.51	8.59	8.83
Nevada	7.23	7.70	7.16	7.31	6.97	7.79	8.41	8.12	8.05	7.99	8.08	7.99	7.73
New Hampshire	15.40	16.60	16.06	16.69	15.98	16.25	16.26	15.88	16.18	16.38	16.32	16.75	16.23
New Jersey	12.36	12.13	12.51	12.41	13.08	13.57	13.58	13.34	12.91	12.73	12.75	12.26	12.80
New Mexico	9.78	10.31	10.14	10.37	10.54	11.23	11.82	11.81	11.46	10.61	10.72	10.38	10.76
New York	14.15	15.22	15.02	14.33	15.68	17.18	18.37	18.61	18.83	17.18	15.60	15.40	16.30
North Carolina	7.90	9.02	9.18	7.96	8.18	8.65	8.83	8.74	8.86	8.83	8.55	9.17	8.66
North Dakota	8.64	8.82	8.82	8.90	9.36	9.65	9.82	9.46	9.78	9.23	9.47	8.37	9.19
Ohio	9.05	9.42	9.78	9.78	9.77	9.87	9.70	9.71	10.06	10.15	10.26	9.86	9.78
Oklahoma	7.71	8.45	6.38	7.91	7.96	7.31	9.34	9.36	9.65	9.86	8.78	8.59	8.44
Oregon	8.93	8.79	9.01	9.07	9.18	8.98	9.06	9.09	9.09	9.25	9.12	8.99	9.05
Pennsylvania	8.27	8.54	8.67	8.63	8.67	8.77	8.77	8.98	9.08	9.29	9.64	9.68	8.92
Rhode Island	16.71	16.91	16.23	15.23	14.60	15.02	15.09	15.12	15.15	15.54	15.41	16.61	15.63
South Carolina	10.03	10.96	10.72	10.21	10.23	10.81	10.36	10.84	10.89	11.26	12.14	11.03	10.79
South Dakota	9.14	11.59	9.58	9.68	10.40	10.66	10.39	10.44	10.33	9.89	9.81	9.91	10.15
Tennessee	10.40	10.55	10.68	10.93	10.83	11.17	11.08	11.03	11.15	10.89	11.23	11.41	10.95
Texas	7.60	15.02	10.79	10.60	8.58	7.57	8.14	8.03	8.16	8.09	8.38	8.05	9.08
Utah	7.57	7.85	8.02	8.06	8.27	8.62	8.33	8.32	8.68	8.35	7.82	7.58	8.12
Vermont	15.92	16.11	16.32	16.53	16.68	16.66	16.50	16.25	16.91	17.33	17.33	17.04	16.63
Virginia	7.36	7.51	7.77	6.62	7.46	7.66	7.90	8.08	8.10	8.34	8.24	8.60	7.80
Washington	9.00	9.17	9.22	9.03	9.15	9.21	9.25	9.12	9.26	9.57	9.41	9.38	9.23
West Virginia	9.02	9.39	9.60	9.72	9.81	9.42	8.85	9.16	9.62	9.99	10.24	9.43	9.52
Wisconsin	10.35	11.08	10.72	10.77	10.99	11.40	11.02	11.14	11.26	10.98	10.95	10.69	10.95
Wyoming	9.41	10.18	9.47	9.90	9.81	10.56	9.63	9.42	9.74	9.68	9.35	9.02	9.68
United States	10.31	11.52	11.18	10.93	10.90	11.34	11.57	11.61	11.76	11.56	11.33	11.20	11.27

Table 8E.2.3 2021 Monthly Residential Natural Gas Prices by State (2021$/MMBtu)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	13.09	13.11	13.76	16.00	18.05	20.63	21.94	22.45	22.81	21.88	17.14	14.81	17.97
Alaska	10.22	10.20	10.22	10.68	11.64	12.71	13.20	12.76	11.27	10.49	9.97	9.95	11.11
Arizona	10.91	12.21	13.02	15.27	18.33	21.30	23.33	23.83	23.37	19.36	17.23	15.02	17.76
Arkansas	9.59	9.23	9.26	12.26	15.28	18.28	20.95	22.14	22.05	20.49	16.43	16.01	16.00
California	15.04	14.87	14.75	15.00	14.84	14.99	15.17	15.26	15.54	17.74	17.54	17.97	15.73
Colorado	6.46	6.37	6.98	8.83	10.23	11.92	15.49	14.74	14.79	11.71	10.41	9.86	10.65
Connecticut	12.77	13.11	13.80	15.23	17.54	21.15	23.16	27.40	24.96	22.15	16.18	15.89	18.61
Delaware	10.74	10.79	10.95	12.28	15.15	19.42	23.60	25.66	24.73	23.20	14.49	12.22	16.94
District of Columbia	10.29	10.82	12.45	14.19	16.60	21.12	24.34	25.06	23.34	25.01	17.58	13.50	17.86
Florida	17.39	18.15	20.48	20.89	23.39	25.42	26.89	28.64	28.39	27.56	24.42	21.17	23.57
Georgia	10.30	10.49	12.02	14.55	19.35	24.92	28.11	29.40	29.92	24.57	14.98	14.18	19.40
Hawaii	38.56	41.43	44.69	41.82	47.60	46.76	49.11	48.06	44.87	49.07	47.33	46.71	45.50
Idaho	6.04	6.18	6.28	6.76	7.36	9.38	9.43	9.82	8.26	7.25	6.85	6.62	7.52
Illinois	6.39	6.32	8.23	11.00	12.73	18.85	21.42	22.43	21.34	16.81	11.43	11.66	14.05
Indiana	6.80	6.53	8.07	9.26	11.33	22.61	23.92	23.57	24.17	15.21	10.46	10.15	14.34
Iowa	5.91	6.84	9.79	10.47	12.84	18.99	19.81	21.52	18.63	13.20	10.93	12.22	13.43
Kansas	7.86	6.91	9.20	11.27	15.36	23.84	23.10	25.05	23.48	15.13	12.23	11.69	15.43
Kentucky	8.59	7.75	10.26	11.56	16.71	23.69	26.34	28.79	25.68	18.24	11.82	13.83	16.94
Louisiana	9.54	8.68	9.50	12.84	16.00	17.47	18.54	20.51	16.87	18.24	13.18	15.76	14.76
Maine	13.19	13.65	14.44	14.89	16.91	24.19	26.13	25.90	27.82	21.02	17.03	16.42	19.30
Maryland	11.03	11.75	12.93	13.24	17.69	20.30	22.69	23.98	23.28	24.11	15.04	15.06	17.59
Massachusetts	14.94	14.37	14.85	15.04	15.20	14.70	16.29	17.70	16.89	16.49	16.85	17.27	15.88
Michigan	7.41	7.31	8.52	8.98	10.48	13.64	14.98	15.17	14.43	10.88	8.94	8.81	10.79
Minnesota	6.85	7.05	7.26	7.95	9.40	12.87	13.52	14.48	14.45	13.96	11.30	10.48	10.80
Mississippi	8.50	8.86	10.16	13.41	16.12	19.59	21.21	23.14	23.21	19.83	13.31	14.49	15.99
Missouri	7.80	7.30	8.40	10.30	12.78	18.13	23.60	25.03	24.32	22.93	11.45	11.72	15.31
Montana	6.83	6.95	7.34	8.45	9.42	11.44	14.01	13.38	12.01	10.89	9.81	9.27	9.98
Nebraska	6.66	6.44	6.94	8.59	10.89	10.45	19.54	20.91	20.32	19.79	13.25	11.14	12.91
Nevada	7.53	7.52	7.75	9.07	10.14	11.86	14.09	15.31	14.49	11.92	10.96	9.47	10.84
New Hampshire	14.05	13.21	13.06	15.23	15.82	18.53	22.09	23.25	23.57	21.19	18.14	19.50	18.14
New Jersey	8.85	9.04	9.16	9.63	10.51	11.56	12.85	13.62	13.19	12.84	10.46	10.51	11.02
New Mexico	6.99	6.91	7.64	9.50	10.81	12.57	16.59	13.86	18.81	16.53	13.56	9.38	11.93
New York	10.75	10.42	11.06	13.28	14.40	17.01	20.38	22.16	21.38	22.19	16.58	14.05	16.14
North Carolina	10.64	10.66	12.88	13.96	15.83	21.44	22.05	18.57	21.98	23.58	14.08	16.62	16.86
North Dakota	5.62	5.78	6.22	7.40	9.23	16.06	26.19	25.74	27.12	15.69	11.32	9.66	13.83
Ohio	6.94	6.95	8.36	10.53	14.19	24.22	29.72	32.13	30.94	20.87	11.30	9.83	17.17
Oklahoma	6.51	6.04	6.13	10.22	12.92	19.19	24.56	27.85	27.14	24.84	16.21	11.97	16.13
Oregon	10.92	8.97	10.30	12.22	12.32	14.51	15.45	16.35	14.52	10.98	12.45	11.44	12.54
Pennsylvania	9.59	9.64	10.53	11.53	12.88	17.14	19.81	20.72	19.92	17.59	12.08	11.93	14.45
Rhode Island	14.33	14.19	14.31	15.08	16.45	18.47	20.68	21.32	21.44	20.45	17.18	16.14	17.50
South Carolina	11.83	11.70	14.48	14.97	21.05	19.01	22.27	21.51	22.52	19.40	11.47	14.02	17.02
South Dakota	6.35	5.84	8.33	10.39	10.54	14.01	17.38	19.03	19.05	13.33	10.98	12.29	12.29
Tennessee	8.31	6.90	7.70	10.20	12.34	17.81	17.83	22.80	18.96	18.25	12.04	11.90	13.75
Texas	10.60	8.57	9.30	13.93	16.40	19.63	21.76	23.70	23.98	22.46	15.58	18.42	17.03
Utah	8.04	8.36	8.22	7.84	8.08	9.68	10.67	11.12	10.51	8.93	8.99	9.79	9.19
Vermont	11.58	11.35	11.56	12.79	14.58	19.25	22.38	23.35	23.50	19.68	14.51	12.89	16.45
Virginia	10.22	11.09	11.79	13.56	17.41	21.50	22.34	24.42	22.62	20.11	13.83	13.38	16.86
Washington	10.25	10.10	10.40	11.38	12.43	14.61	15.95	16.07	13.88	11.13	11.40	10.90	12.37
West Virginia	8.65	8.67	8.95	9.74	10.91	17.68	19.20	20.37	17.30	13.17	10.94	10.47	13.00
Wisconsin	6.81	7.19	7.81	10.20	14.20	17.01	16.39	18.43	16.41	12.59	10.46	9.46	12.25
Wyoming	7.68	7.67	7.72	8.53	9.32	13.06	20.36	21.41	19.73	14.80	11.12	10.87	12.69
United States	9.29	8.96	10.11	11.77	13.58	17.01	19.12	20.14	19.43	16.79	12.65	12.61	14.29

Table 8E.2.4 2021 Monthly Commercial Natural Gas Prices by State (2021$/MMBtu)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	10.86	10.95	11.08	11.49	11.71	12.11	12.28	12.40	12.84	12.51	11.94	12.36	11.88
Alaska	9.34	9.35	9.35	9.48	9.93	10.46	10.76	10.46	9.89	9.55	9.30	9.22	9.76
Arizona	6.61	7.09	7.51	7.90	8.95	9.02	8.77	9.43	9.52	9.58	9.59	9.49	8.62
Arkansas	6.92	6.70	6.51	7.59	8.34	9.43	9.68	9.57	9.49	9.07	11.93	11.55	8.90
California	11.90	11.34	11.57	9.93	10.15	10.22	10.87	10.93	10.90	12.03	13.49	14.26	11.47
Colorado	5.84	5.98	6.32	7.51	8.20	8.86	10.00	10.29	10.68	9.68	9.39	9.09	8.49
Connecticut	8.31	8.80	9.19	9.67	10.72	12.61	12.16	13.35	12.63	12.85	11.58	10.65	11.04
Delaware	9.31	9.48	9.38	10.12	11.28	12.50	12.92	13.53	14.12	13.18	11.31	10.43	11.46
District of Columbia	9.93	10.18	11.93	13.35	13.59	14.78	15.49	15.02	14.39	15.23	15.49	12.54	13.49
Florida	11.45	11.28	11.58	11.45	11.15	11.51	11.21	11.83	12.16	12.03	12.19	12.30	11.68
Georgia	7.11	7.15	8.01	8.13	8.35	8.69	8.30	8.85	8.66	9.05	9.90	9.45	8.47
Hawaii	28.09	30.50	33.14	31.54	33.68	33.76	38.50	32.23	32.51	34.73	34.89	34.37	33.16
Idaho	5.28	5.34	5.43	5.61	5.76	6.31	6.13	6.18	5.76	5.89	6.08	6.00	5.81
Illinois	5.90	5.70	7.13	9.67	13.30	16.65	14.98	17.61	15.93	12.22	8.59	10.84	11.54
Indiana	5.74	5.36	6.64	7.09	7.97	12.12	11.95	11.90	12.52	9.70	8.46	8.55	9.00
Iowa	4.91	6.60	8.05	8.35	9.36	10.62	10.22	10.93	10.79	9.19	9.92	11.01	9.16
Kansas	6.80	6.63	7.51	8.92	11.45	12.42	13.58	13.68	14.54	11.66	10.43	10.11	10.64
Kentucky	7.26	6.62	7.99	8.86	11.49	13.20	13.85	14.51	13.13	11.88	10.03	11.49	10.86
Louisiana	8.97	8.02	8.25	8.91	9.00	8.79	9.87	11.14	10.05	11.73	10.05	12.03	9.73
Maine	10.79	11.38	11.99	11.22	11.64	13.12	13.27	18.52	14.25	13.44	13.41	13.85	13.07
Maryland	9.61	10.25	10.83	10.63	12.99	12.74	13.61	13.73	12.95	15.80	12.02	13.07	12.35
Massachusetts	11.48	11.19	11.30	11.63	11.30	10.76	11.09	11.11	11.71	11.98	12.69	12.66	11.57
Michigan	6.54	6.45	7.26	7.59	8.29	10.14	10.89	10.23	10.84	9.30	8.08	7.84	8.62
Minnesota	5.91	6.07	6.24	6.29	6.85	7.92	8.23	8.93	9.13	10.67	9.78	9.43	7.95
Mississippi	7.64	8.20	9.07	9.49	9.44	9.43	10.00	10.61	11.26	11.96	11.22	12.28	10.05
Missouri	6.35	6.28	6.47	7.13	7.67	8.99	9.92	9.96	9.10	9.73	8.59	9.05	8.27
Montana	6.74	6.99	7.26	8.23	9.06	11.68	11.84	11.44	10.95	10.06	9.36	9.28	9.41
Nebraska	5.46	5.30	5.48	5.56	5.67	5.10	7.36	7.21	8.42	9.25	9.53	9.07	6.95
Nevada	5.42	5.39	5.40	5.72	5.94	5.87	7.16	8.08	7.93	7.51	7.46	7.13	6.58
New Hampshire	10.81	10.07	10.01	11.92	12.70	14.22	16.36	16.54	16.68	15.17	13.86	15.72	13.67
New Jersey	8.51	8.66	8.85	8.44	8.65	9.18	10.09	10.85	11.70	12.56	13.02	12.74	10.27
New Mexico	5.56	5.36	5.83	6.36	7.13	6.33	7.10	8.17	8.16	8.93	10.80	10.31	7.50
New York	7.13	7.11	7.44	7.58	7.13	6.83	7.07	6.95	7.02	8.36	9.23	9.35	7.60
North Carolina	8.16	8.03	9.00	8.85	9.21	9.72	9.91	8.57	9.61	11.43	10.51	13.24	9.69
North Dakota	5.22	5.44	5.57	5.74	5.98	7.34	9.65	9.09	10.29	8.25	9.73	9.37	7.64
Ohio	5.07	5.19	5.80	5.99	6.84	7.97	8.23	8.66	8.92	8.47	7.31	7.13	7.13
Oklahoma	5.46	5.08	5.07	7.75	9.55	12.52	14.75	16.04	14.62	14.74	12.84	9.98	10.70
Oregon	7.69	7.19	7.96	8.74	8.73	9.47	9.57	9.88	9.35	8.35	9.91	9.46	8.86
Pennsylvania	7.98	8.21	8.88	9.28	9.80	11.34	11.38	11.22	11.32	11.15	9.34	10.40	10.02
Rhode Island	11.52	11.46	11.67	12.03	13.00	15.21	17.27	17.81	17.43	17.03	14.47	13.35	14.35
South Carolina	8.86	8.85	9.63	8.61	9.30	8.80	10.20	8.71	9.93	10.45	9.45	12.46	9.61
South Dakota	5.04	4.87	6.80	8.18	8.09	9.35	10.00	11.28	10.70	8.39	9.25	10.83	8.57
Tennessee	7.63	6.85	7.35	8.07	8.36	8.49	9.58	11.70	10.68	11.19	10.88	11.56	9.36
Texas	6.86	6.49	6.91	7.59	8.39	8.47	8.89	9.45	9.83	10.57	10.16	9.87	8.62
Utah	6.88	7.08	7.00	6.56	6.26	6.91	7.27	7.52	7.30	6.83	7.29	8.37	7.11
Vermont	5.89	6.24	6.21	5.49	5.64	5.24	5.51	5.77	6.35	6.98	7.43	7.46	6.18
Virginia	7.77	7.97	8.66	8.70	9.48	10.41	9.98	10.43	10.43	8.70	9.86	10.33	9.39
Washington	8.55	8.33	8.73	9.00	9.29	10.30	10.20	10.14	9.46	9.23	8.86	9.70	9.32
West Virginia	7.40	7.40	7.57	7.98	8.48	10.45	10.01	10.06	9.28	8.85	8.96	8.73	8.76
Wisconsin	5.63	6.56	6.40	8.31	10.66	12.37	8.75	9.70	9.91	8.77	8.97	8.39	8.70
Wyoming	6.46	6.40	6.42	6.75	6.94	7.47	9.09	9.49	9.26	9.32	8.70	9.16	7.96
United States	6.98	6.78	7.03	6.98	7.45	7.95	8.19	8.18	8.15	7.32	7.37	7.14	7.46

8E.2.2 Annual LPG Prices

DOE collected 2020 average liquid petroleum gas (LPG) prices from EIA's 2020 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[6] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state. All prices in 2020$ were converted to 2021$ using the CPI (1.0468 factor) to be consistent with the prices used in the rest of the analysis.[b] DOE also escalated the prices to 2021 using EIA's 2022 Annual Energy Outlook (AEO 2022), see Table 8E.2.5. Table 8E.2.6 shows the resulting annual residential and commercial LPG prices for each state.

Table 8E.2.5 2022 AEO LPG Excalation Factors from 2020 to 2021 (2021$/MMBtu)

State	LPG, Residential			LPG, Commercial		
	2020	2021	Factor	2020	2021	Factor
New England	30.6	25.0	0.82	14.5	19.1	1.32
Middle Atlantic	26.6	24.8	0.93	14.0	20.2	1.44
East North Central	18.0	19.2	1.06	11.3	17.3	1.53
West North Central	14.8	17.5	1.18	11.2	16.5	1.47
South Atlantic	29.5	23.7	0.80	13.3	19.5	1.47
East South Central	21.9	22.6	1.03	11.6	18.5	1.59
West South Central	21.2	22.2	1.04	11.8	18.4	1.55
Mountain	20.7	20.5	0.99	12.8	18.6	1.46
Pacific	24.3	24.6	1.01	15.6	20.2	1.30
United States	21.6	21.5	1.00	12.9	18.8	1.45

[b] https://www.bls.gov/cpi/

Table 8E.2.6 2021 Average Annual LPG Prices by State (2021$/MMBtu)

State	LPG	
	Residential	Commercial
Alabama	22.74	18.60
Alaska	27.15	19.15
Arizona	24.87	22.70
Arkansas	21.74	18.57
California	25.09	20.54
Colorado	18.98	16.33
Connecticut	26.60	19.42
Delaware	20.92	19.53
District of Columbia	23.65	20.71
Florida	28.33	19.49
Georgia	21.44	19.12
Hawaii	42.06	19.91
Idaho	20.65	16.81
Illinois	16.79	17.32
Indiana	20.38	17.45
Iowa	15.40	16.56
Kansas	17.80	16.64
Kentucky	22.22	17.98
Louisiana	25.29	18.21
Maine	22.92	19.27
Maryland	23.39	20.71
Massachusetts	27.87	19.41
Michigan	19.48	17.29
Minnesota	18.46	16.70
Mississippi	24.10	19.13
Missouri	18.69	16.29
Montana	17.39	15.87
Nebraska	15.98	16.49
Nevada	24.54	22.98
New Hampshire	22.94	18.26
New Jersey	29.40	20.48
New Mexico	21.49	17.18
New York	25.58	19.97
North Carolina	22.83	19.26
North Dakota	16.75	16.41
Ohio	23.56	17.24
Oklahoma	17.08	17.28
Oregon	23.04	19.15
Pennsylvania	22.31	20.36
Rhode Island	28.00	19.55
South Carolina	24.18	19.49
South Dakota	17.79	16.33
Tennessee	21.44	18.15
Texas	23.70	18.52
Utah	19.72	16.83
Vermont	22.63	19.37
Virginia	23.76	19.35
Washington	21.59	20.40
West Virginia	24.00	19.49
Wisconsin	16.28	17.13
Wyoming	18.94	16.49
United States	21.96	18.81

8E.3 MONTHLY ENERGY PRICE FACTORS DETERMINATION

For consumer pool heaters, DOE developed monthly energy price factors and used monthly energy consumption data for the life-cycle cost and payback period calculation. DOE developed monthly energy price factors to capture robust seasonal trends in monthly energy prices. To convert available annual energy prices into monthly energy prices, DOE determined monthly energy price factors.

8E.3.1 Monthly Electricity Price Factor Calculations

DOE collected historical electricity prices from 2002 to 2021 from EIA's Form 861M. These data are published annually and include monthly electricity sales, revenues from electricity sales, and average price for the residential, commercial, industrial, and transportation sectors by year and by state. As an example, to illustrate the methodology for producing monthly price factors, the following tables and charts show the calculation of monthly average residential electricity price factors, based on New York historic residential electricity price data. Table 8E.3.1 shows the average residential electricity prices for New York.

Table 8E.3.1 2002-2021 Average Residential Electricity Prices for New York from EIA Data (nominal cents/kWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2002	12.95	13.00	12.81	12.69	13.30	14.01	14.19	14.16	14.42	13.87	13.37	13.19	13.50
2003	12.77	13.30	13.91	14.55	14.77	14.98	15.14	14.94	14.92	14.75	14.23	13.63	14.32
2004	13.32	14.02	13.98	14.03	14.20	14.99	15.36	15.32	15.10	14.93	14.88	14.29	14.53
2005	14.05	14.53	14.40	14.64	15.36	15.58	15.63	16.16	16.69	17.36	17.57	16.53	15.71
2006	16.61	16.66	15.89	16.36	16.56	17.33	17.56	17.74	17.92	17.22	16.33	15.88	16.84
2007	16.09	15.89	16.83	17.14	17.50	18.17	17.27	17.96	17.15	17.48	16.94	16.66	17.09
2008	16.87	17.32	16.93	18.05	18.74	19.41	19.75	20.93	19.50	17.58	16.97	16.63	18.22
2009	16.86	16.75	16.39	16.50	16.87	18.21	18.65	18.19	18.78	18.17	16.82	17.51	17.47
2010	17.30	18.05	17.55	18.92	19.21	19.41	20.11	19.35	20.09	18.36	18.25	17.72	18.69
2011	17.25	17.45	17.58	17.63	18.30	19.07	19.22	19.25	18.84	18.78	17.93	17.26	18.21
2012	16.79	16.51	16.64	16.70	17.33	18.31	18.38	18.12	18.52	18.44	17.44	17.47	17.55
2013	17.93	19.10	18.16	17.67	18.35	19.32	20.03	19.14	19.56	18.88	18.49	18.18	18.74
2014	19.57	21.69	20.90	19.54	20.59	20.88	20.48	19.51	19.41	19.43	19.45	19.26	20.06
2015	19.28	19.75	18.92	17.72	18.06	18.76	18.71	18.38	18.38	18.30	18.23	17.50	18.50
2016	16.56	16.76	16.79	17.38	17.71	17.87	17.93	17.99	18.36	18.26	17.73	17.17	17.54
2017	17.30	17.48	17.02	17.30	18.53	18.74	18.79	18.56	18.80	18.74	17.80	16.99	18.01
2018	17.75	18.19	17.52	17.98	18.51	19.28	19.37	19.02	19.28	19.29	18.17	17.33	18.47
2019	17.30	17.65	16.85	17.54	17.35	18.53	18.64	18.38	18.72	18.58	18.01	17.33	17.91
2020	17.58	17.46	17.20	17.35	18.55	19.13	18.75	18.43	19.01	19.29	18.95	18.26	18.33
2021	18.27	18.78	18.04	18.52	19.89	19.56	19.60	19.92	20.46	20.59	20.04	19.50	19.43

DOE then calculated monthly energy price factors by dividing the monthly prices by the annual average for each year. Table 8D.3.2 and Figure 8D.3.1 show the calculated results for New York. DOE then averaged the monthly energy price factors for 2002 to 2021 (last 20-years) to develop an average energy price factor for each month.

Table 8E.3.2 Monthly Residential Electricity Price Factors for New York (2002-2021)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	0.96	0.96	0.95	0.94	0.99	1.04	1.05	1.05	1.07	1.03	0.99	0.98
2003	0.89	0.93	0.97	1.02	1.03	1.05	1.06	1.04	1.04	1.03	0.99	0.95
2004	0.92	0.96	0.96	0.97	0.98	1.03	1.06	1.05	1.04	1.03	1.02	0.98
2005	0.89	0.93	0.92	0.93	0.98	0.99	0.99	1.03	1.06	1.11	1.12	1.05
2006	0.99	0.99	0.94	0.97	0.98	1.03	1.04	1.05	1.06	1.02	0.97	0.94
2007	0.94	0.93	0.98	1.00	1.02	1.06	1.01	1.05	1.00	1.02	0.99	0.97
2008	0.93	0.95	0.93	0.99	1.03	1.07	1.08	1.15	1.07	0.96	0.93	0.91
2009	0.97	0.96	0.94	0.94	0.97	1.04	1.07	1.04	1.07	1.04	0.96	1.00
2010	0.93	0.97	0.94	1.01	1.03	1.04	1.08	1.04	1.07	0.98	0.98	0.95
2011	0.95	0.96	0.97	0.97	1.00	1.05	1.06	1.06	1.03	1.03	0.98	0.95
2012	0.96	0.94	0.95	0.95	0.99	1.04	1.05	1.03	1.05	1.05	0.99	0.99
2013	0.96	1.02	0.97	0.94	0.98	1.03	1.07	1.02	1.04	1.01	0.99	0.97
2014	0.98	1.08	1.04	0.97	1.03	1.04	1.02	0.97	0.97	0.97	0.97	0.96
2015	1.04	1.07	1.02	0.96	0.98	1.01	1.01	0.99	0.99	0.99	0.99	0.95
2016	0.94	0.96	0.96	0.99	1.01	1.02	1.02	1.03	1.05	1.04	1.01	0.98
2017	0.96	0.97	0.95	0.96	1.03	1.04	1.04	1.03	1.04	1.04	0.99	0.94
2018	0.96	0.98	0.95	0.97	1.00	1.04	1.05	1.03	1.04	1.04	0.98	0.94
2019	0.97	0.99	0.94	0.98	0.97	1.03	1.04	1.03	1.05	1.04	1.01	0.97
2020	0.96	0.95	0.94	0.95	1.01	1.04	1.02	1.01	1.04	1.05	1.03	1.00
2021	0.94	0.97	0.93	0.95	1.02	1.01	1.01	1.03	1.05	1.06	1.03	1.00
20-Year Avg.	0.95	0.97	0.96	0.97	1.00	1.04	1.04	1.04	1.04	1.03	1.00	0.97

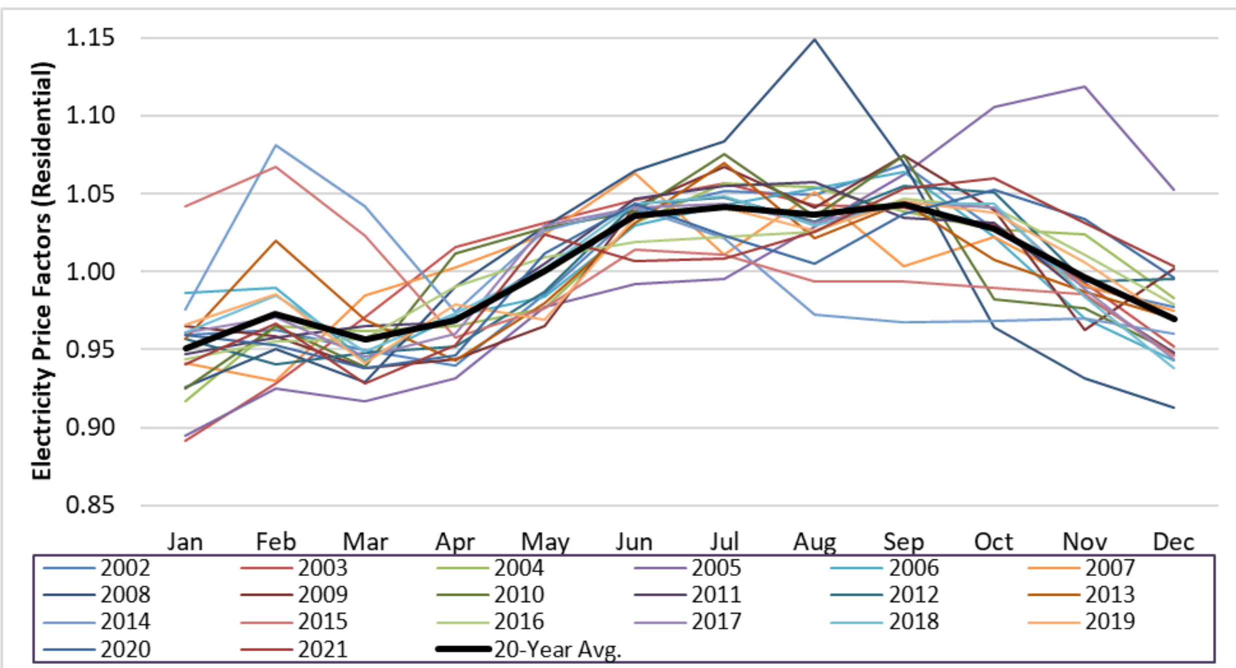

Figure 8E.3.1 Monthly Electricity Price Factors for New York (2002-2021)

DOE performed the same calculations for each state to develop the average monthly residential and commercial energy price factors as shown in Table 8E.3.3 and Table 8E.3.4, respectively.

Table 8E.3.3 Average Monthly Residential Electricity Price Factors (2002-2021)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.93	0.96	0.99	1.03	1.01	1.03	1.02	1.03	1.03	1.03	1.00	0.94
Alaska	0.95	0.95	0.98	0.99	1.02	1.03	1.05	1.03	1.01	1.01	1.00	0.99
Arizona	0.90	0.93	0.94	1.00	1.08	1.06	1.06	1.05	1.05	1.04	0.95	0.94
Arkansas	0.91	0.94	0.96	1.01	1.02	1.05	1.05	1.05	1.05	1.01	1.01	0.95
California	1.01	1.00	0.98	0.91	1.00	1.04	1.05	1.05	1.03	0.91	1.02	1.02
Colorado	0.94	0.96	0.97	0.99	1.00	1.04	1.04	1.04	1.05	1.01	1.00	0.97
Connecticut	0.96	0.99	0.99	1.02	1.03	1.02	0.99	1.00	1.01	1.02	0.99	0.97
Delaware	0.92	0.93	0.95	0.99	1.05	1.04	1.01	1.02	1.03	1.06	1.04	0.97
District of Columbia	0.94	0.96	0.96	0.97	1.01	1.05	1.04	1.05	1.04	1.02	0.99	0.98
Florida	0.98	0.99	0.99	1.00	0.98	1.00	1.00	1.00	1.01	1.01	1.02	1.00
Georgia	0.91	0.94	0.97	0.98	1.01	1.08	1.09	1.10	1.06	1.00	0.96	0.91
Hawaii	0.97	0.98	0.98	0.99	0.99	1.01	1.01	1.01	1.01	1.02	1.02	1.02
Idaho	0.96	0.95	0.96	0.96	1.00	1.05	1.06	1.06	1.00	1.02	0.98	0.97
Illinois	0.91	0.95	0.99	1.03	1.06	1.03	1.00	1.01	1.02	1.05	1.02	0.94
Indiana	0.91	0.94	0.97	1.04	1.05	1.01	0.99	1.00	1.03	1.06	1.03	0.96
Iowa	0.88	0.91	0.94	0.99	1.04	1.08	1.10	1.12	1.06	1.01	0.96	0.91
Kansas	0.90	0.94	0.98	1.02	1.04	1.04	1.05	1.05	1.04	1.01	0.99	0.93
Kentucky	0.93	0.95	0.97	1.02	1.03	1.01	1.00	1.01	1.02	1.05	1.03	0.99
Louisiana	0.92	0.95	0.97	1.00	1.03	1.02	1.03	1.04	1.04	1.04	0.99	0.97
Maine	0.98	0.99	1.00	0.99	1.01	1.01	1.00	1.00	1.01	1.01	1.01	0.98
Maryland	0.94	0.95	0.96	0.98	1.01	1.06	1.04	1.04	1.04	1.03	0.99	0.98
Massachusetts	1.00	1.01	1.01	1.01	1.00	0.99	0.97	0.99	1.01	0.99	0.99	1.02
Michigan	0.96	0.97	0.97	0.98	1.00	1.03	1.04	1.04	1.02	1.01	0.99	0.99
Minnesota	0.93	0.94	0.95	0.98	1.01	1.06	1.07	1.06	1.04	1.02	0.98	0.96
Mississippi	0.93	0.95	0.99	1.03	1.04	1.03	1.01	1.01	1.00	1.01	1.02	0.98
Missouri	0.84	0.86	0.91	0.97	1.09	1.16	1.15	1.15	1.04	0.99	0.95	0.89
Montana	0.94	0.94	0.96	0.97	1.01	1.04	1.05	1.04	1.06	1.03	0.99	0.97
Nebraska	0.84	0.88	0.91	0.97	1.01	1.11	1.13	1.13	1.14	1.01	0.96	0.90
Nevada	0.98	1.01	1.02	1.03	1.01	0.98	0.97	0.96	0.99	1.03	1.04	1.00
New Hampshire	0.97	0.99	0.99	1.01	1.02	1.00	0.98	0.98	1.01	1.03	1.01	1.00
New Jersey	0.96	0.97	0.97	0.98	0.99	1.04	1.06	1.07	1.04	0.98	0.97	0.98
New Mexico	0.94	0.96	0.96	0.97	0.99	1.04	1.06	1.07	1.04	1.04	0.97	0.96
New York	0.95	0.97	0.96	0.97	1.00	1.04	1.04	1.04	1.04	1.03	1.00	0.97
North Carolina	0.93	0.97	0.98	1.03	1.01	0.99	1.01	1.02	1.04	1.06	1.01	0.95
North Dakota	0.84	0.87	0.90	0.96	1.04	1.13	1.11	1.12	1.13	1.04	0.95	0.89
Ohio	0.92	0.93	0.96	1.01	1.04	1.05	1.05	1.05	1.02	1.02	1.00	0.95
Oklahoma	0.85	0.99	0.96	1.04	1.02	1.03	1.03	1.04	1.10	1.08	0.98	0.88
Oregon	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.02	1.02	1.00	0.99
Pennsylvania	0.94	0.96	0.97	0.99	1.02	1.04	1.03	1.03	1.02	1.02	1.00	0.98
Rhode Island	1.00	1.02	1.00	0.99	0.98	0.97	0.95	0.99	1.03	1.00	1.01	1.05
South Carolina	0.95	0.97	0.98	1.02	1.01	1.01	1.01	1.00	1.02	1.02	1.02	0.97
South Dakota	0.89	0.91	0.93	0.97	1.04	1.07	1.07	1.06	1.08	1.06	0.99	0.94
Tennessee	0.96	0.95	0.98	1.01	1.02	1.01	1.00	1.00	0.99	1.03	1.04	1.01
Texas	0.95	0.97	0.99	1.01	1.01	1.03	1.02	1.02	1.02	1.01	1.00	0.98
Utah	0.95	0.96	0.96	0.97	1.01	1.05	1.07	1.07	1.04	0.99	0.97	0.97
Vermont	0.96	0.97	0.98	1.00	1.01	1.01	1.00	1.00	1.01	1.03	1.02	0.99
Virginia	0.92	0.94	0.96	1.00	1.03	1.05	1.05	1.05	1.04	1.02	0.99	0.95
Washington	0.97	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.02	1.01	1.01	1.00
West Virginia	0.94	0.95	0.98	1.01	1.03	1.02	1.00	1.01	1.02	1.05	1.02	0.97
Wisconsin	0.95	0.97	0.97	1.00	1.03	1.03	1.01	1.02	1.03	1.02	1.00	0.97
Wyoming	0.91	0.93	0.95	0.98	1.02	1.05	1.06	1.04	1.06	1.05	0.99	0.95
United States	0.94	0.96	0.97	1.00	1.02	1.03	1.03	1.04	1.03	1.02	1.00	0.97

Table 8E.3.4 Average Monthly Commercial Electricity Price Factors (2002-2021)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.98	0.99	0.99	1.00	0.99	1.02	1.01	1.02	1.01	1.01	1.01	0.98
Alaska	0.96	0.97	0.98	1.00	1.02	1.02	1.02	1.01	1.00	1.01	1.00	1.00
Arizona	0.92	0.94	0.94	0.97	1.05	1.07	1.08	1.07	1.05	1.03	0.95	0.94
Arkansas	0.96	1.00	0.98	0.98	1.00	1.03	1.03	1.03	1.02	1.00	0.99	0.98
California	0.88	0.91	0.90	0.91	0.97	1.11	1.16	1.15	1.12	1.05	0.96	0.90
Colorado	0.92	0.95	0.96	0.99	1.00	1.06	1.04	1.04	1.04	1.02	1.01	0.97
Connecticut	0.99	1.02	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	0.99	0.99
Delaware	0.96	0.99	0.99	0.98	1.01	1.04	1.01	1.01	1.01	1.01	1.01	0.99
District of Columbia	0.96	0.98	0.97	0.98	1.01	1.03	1.01	1.02	1.05	1.01	0.99	0.99
Florida	0.99	1.02	1.01	1.00	0.98	0.98	0.98	0.99	1.00	1.01	1.02	1.01
Georgia	0.98	0.99	0.99	0.99	0.99	1.01	1.02	1.03	1.01	1.00	1.00	0.98
Hawaii	0.98	0.98	0.98	0.98	0.99	0.99	1.00	1.01	1.01	1.02	1.03	1.03
Idaho	0.96	0.98	0.99	1.00	1.00	1.05	1.03	1.03	0.99	1.01	1.00	0.97
Illinois	0.95	0.97	0.99	1.00	1.01	1.02	1.03	1.03	1.01	1.02	0.99	0.96
Indiana	0.96	0.99	1.00	1.01	1.00	1.00	1.00	1.01	1.01	1.01	1.02	1.00
Iowa	0.91	0.93	0.95	0.96	1.00	1.08	1.14	1.15	1.06	0.96	0.94	0.92
Kansas	0.93	0.97	0.99	1.00	1.02	1.05	1.05	1.05	1.03	1.00	0.97	0.95
Kentucky	0.95	0.99	0.98	1.01	1.01	1.01	1.00	1.01	1.01	1.00	1.02	1.01
Louisiana	0.97	1.00	1.01	1.00	1.00	0.99	1.00	1.01	1.00	1.02	1.00	1.01
Maine	1.03	1.07	1.04	0.97	0.96	0.96	0.96	0.96	0.99	0.99	1.03	1.05
Maryland	0.97	0.99	0.97	0.97	0.99	1.03	1.03	1.03	1.05	1.01	0.98	1.00
Massachusetts	0.99	1.01	0.99	0.97	0.95	1.02	1.03	1.03	1.05	0.99	0.96	1.00
Michigan	0.96	0.99	0.99	0.99	1.01	1.02	1.02	1.02	1.00	1.00	1.00	0.99
Minnesota	0.93	0.96	0.95	0.97	1.00	1.09	1.08	1.07	1.04	0.98	0.97	0.95
Mississippi	0.99	1.00	1.01	1.01	1.01	1.00	0.99	0.99	0.98	0.99	1.01	1.02
Missouri	0.87	0.89	0.91	0.92	1.07	1.18	1.18	1.18	1.03	0.93	0.92	0.90
Montana	0.96	0.98	0.98	0.99	1.01	1.01	1.01	1.01	1.02	1.03	1.01	0.99
Nebraska	0.92	0.95	0.97	0.97	1.00	1.07	1.08	1.08	1.08	0.99	0.96	0.95
Nevada	0.99	1.02	1.00	1.00	0.99	0.98	0.99	1.00	1.01	1.02	1.01	0.99
New Hampshire	0.99	1.02	1.00	1.00	1.00	1.00	0.99	0.98	1.00	1.01	1.00	1.01
New Jersey	0.95	0.96	0.96	0.96	0.99	1.09	1.09	1.10	1.05	0.96	0.95	0.95
New Mexico	0.95	0.97	0.97	0.96	0.98	1.04	1.06	1.07	1.03	1.02	0.98	0.98
New York	0.94	0.95	0.94	0.94	0.97	1.06	1.10	1.08	1.08	1.03	0.96	0.95
North Carolina	0.97	1.00	1.00	0.98	0.98	1.00	1.02	1.02	1.02	1.02	0.99	1.00
North Dakota	0.91	0.95	0.96	0.99	1.01	1.06	1.04	1.06	1.07	1.01	0.98	0.96
Ohio	0.96	0.99	1.01	1.01	1.01	1.00	1.00	1.00	1.01	1.01	1.01	0.98
Oklahoma	0.93	0.95	0.93	0.94	0.96	1.08	1.09	1.10	1.10	1.04	0.94	0.93
Oregon	0.98	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	1.01	1.01	0.99
Pennsylvania	0.98	1.00	1.00	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.00	0.99
Rhode Island	1.02	1.06	1.01	0.97	0.98	0.98	0.97	1.00	0.99	0.98	1.00	1.04
South Carolina	0.97	1.00	0.98	0.98	0.98	1.02	1.01	1.01	1.02	0.99	1.02	1.01
South Dakota	0.94	0.98	0.97	0.98	1.00	1.03	1.04	1.04	1.04	1.02	0.99	0.97
Tennessee	0.98	0.98	1.00	0.99	1.00	1.01	1.00	1.00	1.00	1.00	1.02	1.02
Texas	0.98	1.04	1.02	1.00	0.99	1.01	1.00	1.01	1.00	0.98	0.99	0.98
Utah	0.92	0.95	0.96	0.97	1.05	1.10	1.03	1.03	1.07	1.04	0.96	0.91
Vermont	0.98	0.98	0.99	1.00	1.01	1.01	1.00	0.99	1.00	1.02	1.01	1.00
Virginia	0.99	0.99	0.99	0.99	1.00	1.00	1.01	1.01	1.01	1.01	1.01	1.00
Washington	1.00	1.00	1.01	0.99	0.99	0.99	0.99	0.98	1.00	1.01	1.02	1.02
West Virginia	0.96	1.00	1.01	1.02	1.01	0.98	0.97	0.99	1.00	1.03	1.04	0.99
Wisconsin	0.96	0.98	0.97	0.99	1.01	1.03	1.03	1.03	1.03	1.00	1.00	0.97
Wyoming	0.95	0.97	0.98	1.01	1.02	1.03	1.01	1.00	1.02	1.03	1.01	0.95
United States	0.95	0.98	0.98	0.97	0.99	1.03	1.05	1.04	1.04	1.01	0.99	0.97

8E.3.2 Monthly Natural Gas Price Factor Calculations

DOE collected historical natural gas prices from 2002 to 2021 from the EIA's Natural Gas Navigator. The Natural Gas Navigator includes annual and monthly natural gas prices for residential, commercial, and industrial consumers by year and by state. Again, as an example for how DOE determined monthly natural gas price factors, the methodology used to determine monthly average price factors can be seen below. Table 8E.3.5 shows the historic average residential gas prices for New York.

Table 8E.3.5 2002-2021 Average Residential Natural Gas Prices for New York ($/tcf)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2002	9.35	8.65	9.17	9.34	9.96	11.66	13.04	13.18	13.21	11.84	10.08	9.48	9.35
2003	9.63	9.88	11.69	12.22	12.93	14.71	16.01	16.17	15.58	13.01	12.02	11.36	9.63
2004	11.41	11.33	11.48	11.51	13.07	15.34	16.29	16.89	16.22	14.41	13.44	13.19	11.41
2005	12.80	12.65	12.42	13.45	14.49	16.16	17.62	18.48	20.78	22.24	20.21	17.44	12.80
2006	16.61	15.11	13.99	14.58	16.09	16.69	18.04	18.91	18.43	13.37	14.75	14.97	16.61
2007	15.24	14.43	15.08	15.47	17.33	19.59	19.95	18.94	18.53	18.64	16.04	14.83	15.24
2008	14.99	14.91	15.21	16.76	19.95	22.88	24.96	24.20	21.66	18.42	16.48	16.26	14.99
2009	15.46	14.84	14.63	14.19	15.13	16.82	18.24	17.81	17.74	14.71	14.97	14.02	15.46
2010	12.97	13.01	13.60	15.08	15.82	18.42	20.00	20.17	18.54	16.47	13.88	12.09	12.97
2011	12.05	12.27	12.73	13.60	15.88	19.74	19.77	19.78	19.75	16.56	13.93	12.65	12.05
2012	11.67	11.69	12.99	13.06	15.13	18.00	17.40	18.78	18.16	15.26	11.35	11.97	11.67
2013	11.27	10.80	11.41	12.65	15.73	18.16	19.25	18.99	18.42	16.12	12.27	10.50	11.27
2014	11.18	11.32	11.78	12.49	14.55	17.99	18.99	18.88	17.86	15.99	12.27	10.66	11.18
2015	10.51	9.79	9.34	10.19	12.68	16.26	17.09	17.30	17.50	14.24	12.26	11.43	10.51
2016	10.30	9.45	9.64	9.88	10.99	14.69	16.64	17.86	17.34	14.87	10.95	9.60	10.30
2017	9.86	11.04	10.81	11.09	14.45	16.28	19.14	19.06	18.12	17.17	13.07	10.52	9.86
2018	9.51	11.23	12.09	11.29	14.19	19.32	20.10	20.83	20.14	17.15	12.18	11.64	9.51
2019	12.28	11.44	10.86	12.09	13.99	17.06	19.86	20.14	19.97	16.89	12.45	10.75	12.28
2020	11.37	11.62	11.93	12.07	11.56	16.03	19.34	19.82	19.24	16.08	13.67	12.15	11.37
2021	11.15	10.81	11.47	13.77	14.93	17.64	21.13	22.98	22.17	23.01	17.19	14.57	11.15

DOE then calculated monthly energy price factors for each year by dividing the residential natural gas prices for each month by the natural gas annual average price for each year. Table 8E.3.6 and Figure 8E.3.2 show the calculated results for New York. DOE then averaged the monthly energy price factors for 2002 to 2021 (last 20-years) to develop an average energy price factor for each month.

Table 8E.3.6 **Monthly Natural Gas Price Factors for New York (2002-2021)**

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2002	0.87	0.80	0.85	0.87	0.93	1.08	1.21	1.23	1.23	1.10	0.94	0.88
2003	0.74	0.76	0.90	0.94	1.00	1.14	1.24	1.25	1.20	1.01	0.93	0.88
2004	0.83	0.83	0.84	0.84	0.95	1.12	1.19	1.23	1.18	1.05	0.98	0.96
2005	0.77	0.76	0.75	0.81	0.87	0.98	1.06	1.12	1.25	1.34	1.22	1.05
2006	1.04	0.95	0.88	0.91	1.01	1.05	1.13	1.18	1.15	0.84	0.92	0.94
2007	0.90	0.85	0.89	0.91	1.02	1.15	1.17	1.11	1.09	1.10	0.94	0.87
2008	0.79	0.79	0.81	0.89	1.06	1.21	1.32	1.28	1.15	0.98	0.87	0.86
2009	0.98	0.94	0.93	0.90	0.96	1.07	1.16	1.13	1.13	0.94	0.95	0.89
2010	0.82	0.82	0.86	0.95	1.00	1.16	1.26	1.27	1.17	1.04	0.88	0.76
2011	0.77	0.78	0.81	0.86	1.01	1.26	1.26	1.26	1.26	1.05	0.89	0.80
2012	0.80	0.80	0.89	0.89	1.03	1.23	1.19	1.28	1.24	1.04	0.78	0.82
2013	0.77	0.74	0.78	0.86	1.08	1.24	1.32	1.30	1.26	1.10	0.84	0.72
2014	0.77	0.78	0.81	0.86	1.00	1.24	1.31	1.30	1.23	1.10	0.85	0.74
2015	0.80	0.74	0.71	0.77	0.96	1.23	1.29	1.31	1.32	1.08	0.93	0.86
2016	0.81	0.75	0.76	0.78	0.87	1.16	1.31	1.41	1.37	1.17	0.86	0.76
2017	0.69	0.78	0.76	0.78	1.02	1.15	1.35	1.34	1.27	1.21	0.92	0.74
2018	0.64	0.75	0.81	0.75	0.95	1.29	1.34	1.39	1.35	1.15	0.81	0.78
2019	0.83	0.77	0.73	0.82	0.94	1.15	1.34	1.36	1.35	1.14	0.84	0.73
2020	0.78	0.80	0.82	0.83	0.79	1.10	1.33	1.36	1.32	1.10	0.94	0.83
2021	0.67	0.65	0.69	0.82	0.89	1.05	1.26	1.37	1.32	1.37	1.03	0.87
20-Year Avg.	0.80	0.79	0.81	0.85	0.97	1.15	1.25	1.27	1.24	1.10	0.92	0.84

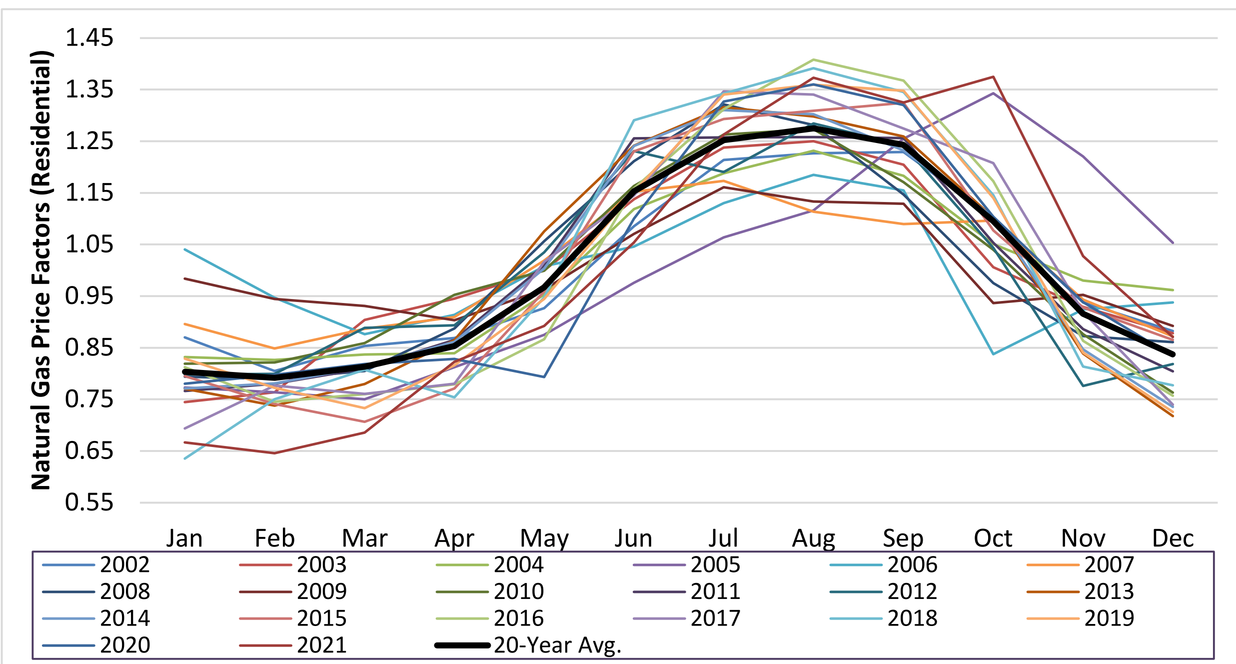

Figure 8E.3.2 Monthly Natural Gas Price Factors for New York (2002-2021)

DOE performed the same calculations for each state to develop the average monthly residential and commercial energy price factors shown in Table 8E.3.7 and Table 8E.3.8, respectively.

Table 8E.3.7 Average Monthly Residential Natural Gas Price Factors (2002-2021)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.79	0.78	0.81	0.91	1.03	1.14	1.19	1.20	1.20	1.16	0.97	0.84
Alaska	0.93	0.94	0.92	0.95	1.01	1.08	1.16	1.14	1.04	0.96	0.93	0.96
Arizona	0.74	0.78	0.84	0.92	1.03	1.14	1.24	1.27	1.24	1.10	0.91	0.78
Arkansas	0.73	0.73	0.76	0.86	0.95	1.18	1.28	1.33	1.30	1.16	0.89	0.78
California	1.00	0.98	0.94	0.90	0.96	1.02	1.04	1.03	1.02	1.02	0.98	1.00
Colorado	0.78	0.78	0.82	0.85	0.99	1.25	1.38	1.39	1.23	0.92	0.83	0.79
Connecticut	0.80	0.81	0.83	0.88	0.99	1.12	1.24	1.28	1.25	1.07	0.89	0.84
Delaware	0.72	0.74	0.78	0.84	0.98	1.17	1.30	1.37	1.33	1.17	0.84	0.75
District of Columbia	0.83	0.81	0.84	0.90	1.02	1.13	1.23	1.21	1.20	1.06	0.92	0.84
Florida	0.81	0.81	0.87	0.92	0.95	1.08	1.14	1.17	1.15	1.13	1.02	0.89
Georgia	0.66	0.70	0.74	0.88	1.08	1.27	1.34	1.36	1.35	1.10	0.80	0.72
Hawaii	0.93	0.96	0.98	0.99	1.01	1.02	1.03	1.03	1.03	1.03	1.00	0.98
Idaho	0.92	0.92	0.95	0.96	1.00	1.08	1.13	1.16	1.08	0.98	0.92	0.91
Illinois	0.70	0.71	0.76	0.83	1.02	1.18	1.44	1.46	1.35	0.96	0.80	0.74
Indiana	0.71	0.72	0.80	0.92	1.06	1.30	1.45	1.43	1.20	0.86	0.73	0.71
Iowa	0.70	0.71	0.78	0.80	0.94	1.22	1.42	1.47	1.41	1.03	0.82	0.72
Kansas	0.67	0.68	0.72	0.87	1.03	1.28	1.39	1.48	1.37	1.06	0.75	0.69
Kentucky	0.68	0.68	0.71	0.82	1.03	1.30	1.41	1.45	1.38	1.01	0.77	0.72
Louisiana	0.76	0.76	0.82	0.91	0.99	1.09	1.20	1.22	1.18	1.16	0.93	0.78
Maine	0.90	0.93	0.92	0.94	0.94	1.00	1.12	1.16	1.09	0.97	0.91	0.93
Maryland	0.77	0.76	0.79	0.88	1.04	1.21	1.30	1.33	1.28	0.96	0.84	0.80
Massachusetts	0.96	0.96	0.96	0.98	0.99	0.98	1.07	1.12	1.08	0.93	0.96	1.00
Michigan	0.80	0.81	0.83	0.88	1.01	1.18	1.29	1.33	1.22	0.96	0.86	0.83
Minnesota	0.85	0.85	0.87	0.87	0.99	1.18	1.27	1.25	1.17	0.93	0.84	0.87
Mississippi	0.74	0.75	0.83	0.92	1.05	1.18	1.17	1.20	1.20	1.14	0.92	0.81
Missouri	0.63	0.63	0.66	0.78	0.95	1.25	1.46	1.53	1.43	1.18	0.82	0.69
Montana	0.86	0.87	0.87	0.90	0.95	1.07	1.23	1.32	1.19	0.97	0.90	0.87
Nebraska	0.71	0.72	0.74	0.81	0.93	1.13	1.35	1.42	1.37	1.14	0.86	0.77
Nevada	0.79	0.81	0.85	0.94	1.03	1.10	1.20	1.25	1.20	1.09	0.93	0.82
New Hampshire	0.86	0.85	0.86	0.90	0.93	1.00	1.20	1.27	1.23	1.05	0.91	0.92
New Jersey	0.89	0.88	0.89	0.89	0.98	1.08	1.14	1.17	1.14	1.05	0.96	0.91
New Mexico	0.75	0.75	0.77	0.83	0.95	1.16	1.30	1.27	1.32	1.17	0.90	0.75
New York	0.80	0.79	0.81	0.85	0.97	1.15	1.25	1.28	1.24	1.03	0.92	0.84
North Carolina	0.71	0.72	0.74	0.87	1.07	1.26	1.34	1.32	1.31	1.08	0.80	0.77
North Dakota	0.70	0.70	0.73	0.78	0.95	1.34	1.50	1.49	1.37	0.79	0.76	0.72
Ohio	0.66	0.67	0.68	0.76	0.95	1.24	1.49	1.56	1.45	1.02	0.76	0.70
Oklahoma	0.58	0.59	0.62	0.77	0.97	1.23	1.42	1.54	1.48	1.31	0.86	0.62
Oregon	0.88	0.88	0.90	0.93	1.00	1.07	1.16	1.23	1.15	0.99	0.87	0.88
Pennsylvania	0.77	0.78	0.80	0.84	0.97	1.18	1.32	1.37	1.30	1.03	0.85	0.80
Rhode Island	0.83	0.84	0.85	0.91	0.98	1.08	1.18	1.23	1.21	1.09	0.93	0.87
South Carolina	0.69	0.70	0.74	0.88	1.11	1.21	1.35	1.35	1.32	1.08	0.78	0.70
South Dakota	0.77	0.79	0.84	0.85	0.91	1.15	1.36	1.41	1.32	0.96	0.85	0.79
Tennessee	0.73	0.73	0.71	0.84	1.00	1.19	1.30	1.30	1.30	1.15	0.87	0.72
Texas	0.63	0.66	0.72	0.88	1.06	1.19	1.28	1.36	1.32	1.19	0.91	0.70
Utah	0.93	0.95	0.96	0.93	0.92	1.01	1.10	1.15	1.12	1.00	0.96	0.97
Vermont	0.81	0.79	0.81	0.84	0.92	1.10	1.26	1.33	1.28	1.09	0.91	0.85
Virginia	0.75	0.75	0.76	0.85	0.98	1.15	1.34	1.33	1.31	1.00	0.84	0.79
Washington	0.88	0.88	0.89	0.93	0.96	1.09	1.18	1.22	1.13	0.97	0.91	0.89
West Virginia	0.77	0.78	0.79	0.85	0.99	1.17	1.37	1.39	1.25	0.96	0.83	0.80
Wisconsin	0.84	0.84	0.88	0.84	0.97	1.12	1.28	1.31	1.19	0.87	0.89	0.86
Wyoming	0.76	0.77	0.79	0.82	0.88	1.07	1.41	1.50	1.35	1.01	0.84	0.79
United States	0.79	0.79	0.82	0.88	1.01	1.17	1.27	1.31	1.25	1.02	0.87	0.82

Table 8E.3.8 Monthly Commercial Natural Gas Price Factors (2002-2021)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.95	0.95	0.95	1.00	1.01	1.02	1.02	1.03	1.05	1.04	1.02	0.98
Alaska	1.02	1.02	0.99	0.98	0.96	0.97	1.00	1.01	1.00	1.01	1.01	1.03
Arizona	0.97	0.98	1.00	1.00	1.02	1.01	1.02	1.02	1.02	1.02	0.99	0.97
Arkansas	0.93	0.92	0.94	0.97	0.97	1.06	1.07	1.07	1.04	1.00	1.00	0.97
California	1.06	1.03	1.01	0.93	0.90	0.96	0.99	0.98	0.96	0.96	1.02	1.09
Colorado	0.91	0.90	0.92	0.93	1.00	1.08	1.15	1.15	1.11	0.98	0.95	0.92
Connecticut	0.93	0.93	0.93	0.98	1.03	1.09	1.07	1.06	1.04	0.99	0.97	0.94
Delaware	0.87	0.89	0.92	0.97	1.03	1.08	1.12	1.13	1.11	1.07	0.93	0.88
District of Columbia	0.99	0.98	0.99	1.02	1.00	1.01	1.03	1.00	0.99	0.98	1.02	0.98
Florida	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.00	0.99	1.00	1.01
Georgia	0.89	0.90	0.93	0.99	1.05	1.09	1.10	1.11	1.08	1.03	0.89	0.88
Hawaii	0.93	0.96	0.99	0.99	1.01	1.03	0.98	1.02	1.02	1.03	1.00	0.99
Idaho	0.97	0.97	0.99	1.01	1.02	1.02	1.03	1.03	1.02	0.99	0.98	0.96
Illinois	0.78	0.78	0.79	0.89	1.01	1.16	1.31	1.25	1.22	0.95	0.81	0.81
Indiana	0.86	0.86	0.95	1.02	1.11	1.22	1.22	1.19	0.98	0.85	0.84	0.85
Iowa	0.90	0.91	0.96	0.91	1.00	1.10	1.16	1.16	1.11	0.91	0.95	0.94
Kansas	0.80	0.81	0.85	0.97	1.07	1.17	1.21	1.22	1.21	1.03	0.85	0.81
Kentucky	0.85	0.84	0.86	0.95	1.00	1.14	1.15	1.17	1.14	1.01	0.92	0.89
Louisiana	1.03	0.99	1.01	0.97	0.98	0.94	1.00	0.92	0.97	1.01	1.04	0.99
Maine	1.06	1.08	1.05	1.05	0.96	0.88	0.99	0.93	0.97	0.90	0.98	1.05
Maryland	0.95	0.95	0.95	0.97	1.02	1.05	1.05	1.05	1.05	0.95	0.98	0.98
Massachusetts	1.06	1.06	1.06	1.07	1.00	0.92	0.95	0.95	0.95	0.88	1.00	1.09
Michigan	0.90	0.91	0.92	0.93	1.00	1.09	1.14	1.14	1.11	0.99	0.94	0.93
Minnesota	0.98	0.98	1.00	0.96	0.99	1.06	1.08	1.05	1.02	0.86	0.93	1.00
Mississippi	0.99	1.01	1.03	0.96	0.99	0.96	0.96	0.89	0.95	1.03	1.04	1.03
Missouri	0.87	0.86	0.87	0.93	0.98	1.08	1.15	1.16	1.12	1.07	0.99	0.92
Montana	0.90	0.91	0.92	0.94	0.98	1.02	1.15	1.17	1.13	0.92	0.93	0.92
Nebraska	1.01	1.00	1.00	0.98	0.95	0.97	1.02	1.03	0.97	0.98	1.00	1.04
Nevada	0.95	0.96	0.97	0.98	1.00	1.01	1.04	1.06	1.05	1.03	0.99	0.96
New Hampshire	0.94	0.94	0.94	0.97	0.97	0.98	1.11	1.13	1.10	0.99	0.95	0.98
New Jersey	1.02	1.01	1.02	0.91	0.95	1.00	1.03	1.00	0.96	0.99	1.06	1.06
New Mexico	0.94	0.93	0.92	0.87	0.95	1.01	1.07	1.09	1.07	1.07	1.04	0.99
New York	1.07	1.07	1.07	1.03	1.00	0.97	0.92	0.89	0.86	0.97	1.02	1.08
North Carolina	0.95	0.93	0.93	0.98	1.01	1.03	1.07	1.02	1.03	1.01	1.02	0.97
North Dakota	0.96	0.94	0.95	0.92	0.99	1.10	1.09	1.06	0.99	0.86	0.97	0.97
Ohio	0.92	0.92	0.91	0.95	1.01	1.09	1.11	1.11	1.08	1.01	0.94	0.94
Oklahoma	0.70	0.70	0.73	0.86	1.01	1.18	1.27	1.34	1.29	1.23	0.96	0.74
Oregon	0.92	0.96	0.98	0.99	1.00	1.02	1.03	1.06	1.04	1.00	0.92	0.97
Pennsylvania	0.91	0.93	0.95	0.96	1.04	1.09	1.12	1.10	1.06	0.99	0.93	0.93
Rhode Island	0.84	0.85	0.86	0.91	0.97	1.09	1.17	1.20	1.18	1.09	0.94	0.89
South Carolina	1.03	1.01	0.98	0.99	0.95	0.99	0.99	0.92	0.97	0.99	1.05	1.03
South Dakota	0.94	0.94	0.99	0.88	0.96	1.00	1.12	1.14	1.08	0.93	0.95	0.96
Tennessee	0.95	0.94	0.89	0.96	0.98	1.02	1.06	1.02	1.05	0.99	1.01	0.93
Texas	0.88	0.93	0.93	0.95	0.99	1.03	1.05	1.05	1.06	1.00	1.03	0.99
Utah	1.01	1.02	1.02	0.97	0.92	0.95	1.01	1.04	1.02	0.98	1.00	1.05
Vermont	1.05	1.05	1.03	1.01	1.00	0.96	0.96	0.96	0.98	0.96	1.00	1.04
Virginia	0.97	0.97	0.94	0.97	1.01	1.06	1.05	0.99	1.05	0.99	0.97	1.00
Washington	0.92	0.96	0.96	0.97	0.95	1.03	1.06	1.08	1.04	0.99	0.98	0.96
West Virginia	0.89	0.89	0.90	0.95	1.03	1.12	1.14	1.15	1.10	1.00	0.93	0.91
Wisconsin	1.02	1.01	1.04	0.95	0.95	1.03	1.02	1.01	0.99	0.88	1.03	1.03
Wyoming	0.95	0.95	0.95	0.94	0.95	1.01	1.08	1.10	1.09	1.02	0.99	0.96
United States	0.96	0.96	0.97	0.98	1.01	1.04	1.05	1.04	1.03	0.99	0.98	0.98

8E.3.3 Monthly LPG Price Factor Calculations

DOE collected historical LPG prices from 1995 to 2009 from EIA's Short-Term Energy Outlook. The Short-Term Energy Outlook includes monthly LPG prices by Census Region (Northeast, South, Midwest, and West).[c]

The same process as used for electricity and natural gas price factors was used for calculating the monthly LPG price factors. These monthly price factors were calculated below, using data from the Northeast region. Table 8E.3.9 shows the Northeast residential LPG prices from 1995 to 2009.

Table 8E.3.9 Average Residential LPG Prices for the Northeast (nominal cents/gallon)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1995	119.1	118.3	120.1	121.4	124.4	125.7	126.2	124.8	121.9	121.0	117.9	117.0	121.5
1996	122.6	125.4	128.0	124.7	129.9	130.6	128.9	127.2	127.3	132.8	135.3	144.8	129.8
1997	142.9	136.8	131.2	130.6	130.3	129.5	129.8	127.0	125.7	126.7	122.8	122.2	129.6
1998	121.4	120.2	119.6	122.6	124.0	124.2	122.4	121.0	119.3	117.6	115.1	114.1	120.1
1999	112.1	113.0	113.5	118.1	122.0	124.4	125.6	128.6	127.1	129.3	128.3	127.6	122.5
2000	131.9	147.8	147.8	144.8	148.4	151.4	155.4	154.3	156.7	158.7	156.1	159.9	151.1
2001	175.7	169.8	161.8	160.2	162.3	160.1	155.7	152.4	149.8	149.9	144.1	138.8	156.7
2002	138.9	137.7	138.5	143.3	142.0	144.4	143.0	141.0	141.3	142.1	141.5	141.5	141.3
2003	149.8	166.0	181.6	164.4	161.3	160.5	159.4	155.8	154.6	155.2	154.5	158.0	160.1
2004	168.5	173.4	170.5	167.5	170.2	173.3	173.0	176.4	181.0	187.3	192.6	187.1	176.7
2005	185.9	186.1	189.6	196.8	199.3	199.8	202.2	204.6	217.1	224.1	219.5	217.3	203.5
2006	220.6	220.2	220.0	225.2	231.3	237.4	242.0	243.5	239.7	232.0	228.5	227.9	230.7
2007	227.2	228.6	234.5	238.7	247.1	251.5	253.2	252.4	253.7	259.8	273.9	275.4	249.7
2008	281.9	280.0	284.4	291.9	306.1	319.5	333.0	328.9	323.9	304.7	280.2	266.9	300.1
2009	267.9	267.1	266.7	263.4	257.8	255.4	255.0	250.6	249.3	249.6	251.7	254.7	257.4

DOE then calculated monthly energy price factors for each year by dividing the prices for each month by the average price for each year. Table 8E.3.10 and Figure 8E.3.3 show the calculated results for the Northeast.

[c] Refer to cwww2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf.

Table 8E.3.10 Monthly Residential LPG Price Factors for the Northeast (1995-2009)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	0.98	0.97	0.99	1.00	1.02	1.03	1.04	1.03	1.00	1.00	0.97	0.96
1996	0.94	0.97	0.99	0.96	1.00	1.01	0.99	0.98	0.98	1.02	1.04	1.12
1997	1.10	1.06	1.01	1.01	1.01	1.00	1.00	0.98	0.97	0.98	0.95	0.94
1998	1.01	1.00	1.00	1.02	1.03	1.03	1.02	1.01	0.99	0.98	0.96	0.95
1999	0.92	0.92	0.93	0.96	1.00	1.02	1.03	1.05	1.04	1.06	1.05	1.04
2000	0.87	0.98	0.98	0.96	0.98	1.00	1.03	1.02	1.04	1.05	1.03	1.06
2001	1.12	1.08	1.03	1.02	1.04	1.02	0.99	0.97	0.96	0.96	0.92	0.89
2002	0.98	0.97	0.98	1.01	1.01	1.02	1.01	1.00	1.00	1.01	1.00	1.00
2003	0.94	1.04	1.13	1.03	1.01	1.00	1.00	0.97	0.97	0.97	0.97	0.99
2004	0.95	0.98	0.96	0.95	0.96	0.98	0.98	1.00	1.02	1.06	1.09	1.06
2005	0.91	0.91	0.93	0.97	0.98	0.98	0.99	1.01	1.07	1.10	1.08	1.07
2006	0.96	0.95	0.95	0.98	1.00	1.03	1.05	1.06	1.04	1.01	0.99	0.99
2007	0.91	0.92	0.94	0.96	0.99	1.01	1.01	1.01	1.02	1.04	1.10	1.10
2008	0.94	0.93	0.95	0.97	1.02	1.06	1.11	1.10	1.08	1.02	0.93	0.89
2009	1.04	1.04	1.04	1.02	1.00	0.99	0.99	0.97	0.97	0.97	0.98	0.99
Avg	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00

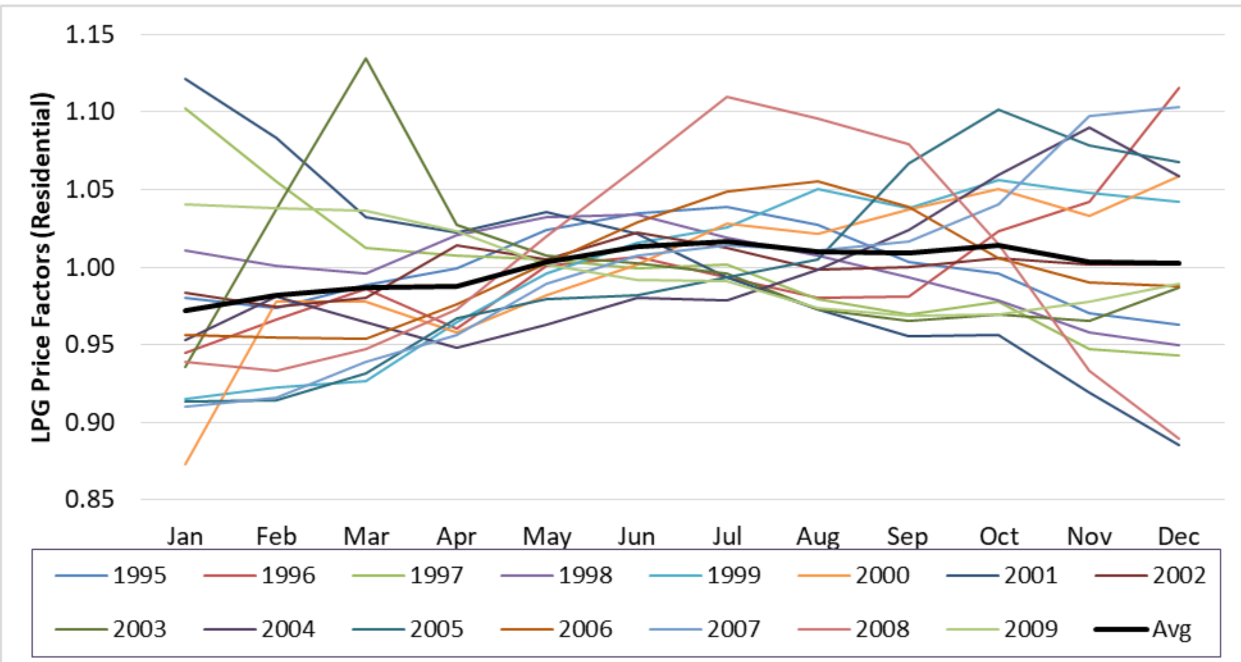

Figure 8E.3.3 Monthly Residential LPG Factors for the Northeast (1995-2009)

DOE then averaged the monthly energy price factors for 1995 to 2009 to develop an average energy price factor for each month. DOE performed the same calculations for each Census region to develop the average monthly residential and commerial energy price factors shown in Table 8E.3.11 and Table 8E.3.12, respectively.

Table 8E.3.11 Average Monthly Residential LPG Energy Price Factors (1995-2009)

Census Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northeast	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00
Midwest	1.04	1.04	1.03	1.01	1.00	0.97	0.94	0.93	0.96	0.98	1.03	1.07
South	1.04	1.04	1.03	1.01	0.99	0.97	0.95	0.93	0.96	1.00	1.03	1.06
West	1.05	1.05	1.03	1.01	0.99	0.96	0.92	0.91	0.95	1.01	1.04	1.08
U.S.	1.02	1.03	1.02	1.02	1.02	1.00	0.95	0.93	0.96	0.99	1.02	1.05

Table 8E.3.12 Average Monthly Commercial LPG Energy Price Factors (1995-2009)

Census Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northeast	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00
Midwest	1.04	1.04	1.03	1.01	1.00	0.97	0.94	0.93	0.96	0.98	1.03	1.07
South	1.04	1.04	1.03	1.01	0.99	0.97	0.95	0.93	0.96	1.00	1.03	1.06
West	1.05	1.05	1.03	1.01	0.99	0.96	0.92	0.91	0.95	1.01	1.04	1.08
U.S.	1.02	1.03	1.02	1.02	1.02	1.00	0.95	0.93	0.96	0.99	1.02	1.05

8E.4 SEASONAL MARGINAL PRICE FACTORS DETERMINATION

Marginal energy prices are the prices consumers pay for the last unit of energy used. DOE used the marginal energy prices for each building to determine the cost of saved energy associated with the use of higher-efficiency products. Because marginal prices reflect a change in a consumer's bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with possible changes to efficiency standards.

EIA provides historical monthly electricity and natural gas consumption and expenditures by state. This data was used to determine 10-year average marginal prices by state, which are then used to convert average monthly energy prices into marginal monthly energy prices. Because a pool heater operates during both the heating and cooling seasons, DOE determined summer and winter marginal price factors.

For LPG, DOE used average energy prices only, as the data necessary for estimating marginal prices were not available.

8E.4.1 Marginal Price Factor Calculation Methodolgy

The methodology used for estimating marginal energy prices follows previous research found in Lawrence Berkeley National Laboratory (LBNL) reports.[7,8,9,10] Calculating marginal energy prices for an individual customer requires a detailed knowledge of the consumer's bill including utility tariff values and structure and energy use as well as items not normally available on utility tariffs such as taxes, special fees, and one-time surcharges or rebates included in the energy bill. Instead DOE relies on aggregate EIA historical monthly electricity and natural gas consumption and expenditures by state. The use of billing data avoids having to estimate the effect of non-tariff items on consumer marginal energy prices.

Seasonal marginal energy prices by state were calculated using a linear regression of monthly expenditures to monthly customer energy consumption. DOE interpreted the slope of the regression line for each state as the average seasonal marginal energy price for that state, as follows:

$$Expenditures = MarginalPrice \times EnergyUse + FixedCost$$

Eq. 8E.1

Where:

Expenditures = total monthly expenditures for electricity or natural gas by state,
FixedCost = total monthly fixed cost for electricity or natural gas by state, and
EnergyUse = total monthly electricity or natural gas usage

For each state, DOE performed this calculation over a 10-year period (2011-2020) to reduce annual fluctuations and improve accuracy. DOE then normalized each annual seasonal marginal price by the corresponding annual seasonal price, as follows:

$$MarginalPriceFactor_{Season} = \frac{MarginalPrice_{Season}}{AveragePrice_{Season}}$$

Eq. 8E.2

Where:

Season = summer or winter.

Based on consumption data, DOE defined winter as the 5 months from November through March and summer or non-winter as the rest of the year (the remaining 7 months). DOE kept the marginal energy prices only for regression values with r-squared greater or equal to 75%. 75% limit gets a close correlation in the cost and consumption data, without excluding too many state records from the analysis or losing the linearity of the relationship between the seasonal costs and consumption.

As an example, Figure 8E.4.1 and Figure 8E.4.2 show the 2021 monthly residential expenditure and consumption data for Virginia for electricity and natural gas, respectively. Figure 8E.4.3 and Figure 8E.4.4 show the associated seasonal regression lines. The slopes of these regression lines are DOE's estimate of the 2021 seasonal residential marginal prices for Virginia for electricity and natural gas, respectively. Table 8E.4.1 and Table 8E.4.2 show the calculated seasonal marginal price (and r-squared value from the linear regression), the corresponding seasonal average price, and the resulting seasonal marginal price factor for Virginia for electricity and natural gas, respectively.

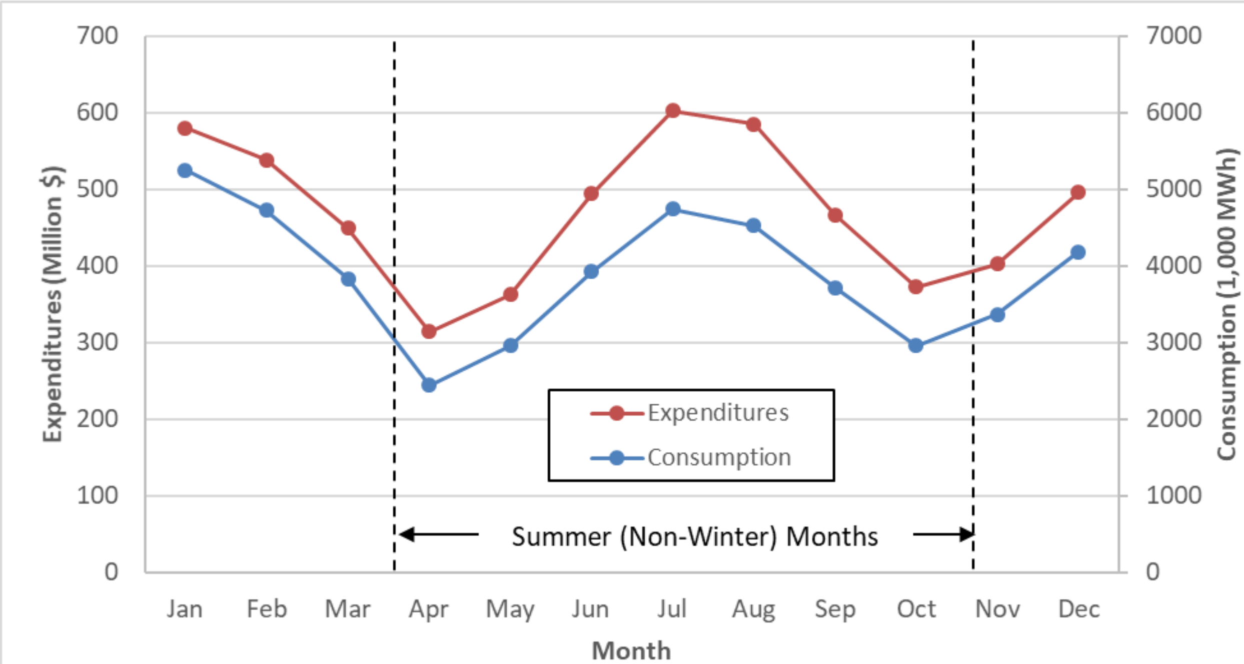

Figure 8E.4.1 2021 Monthly Residential Electricty Expenditures and Energy Use for Virginia

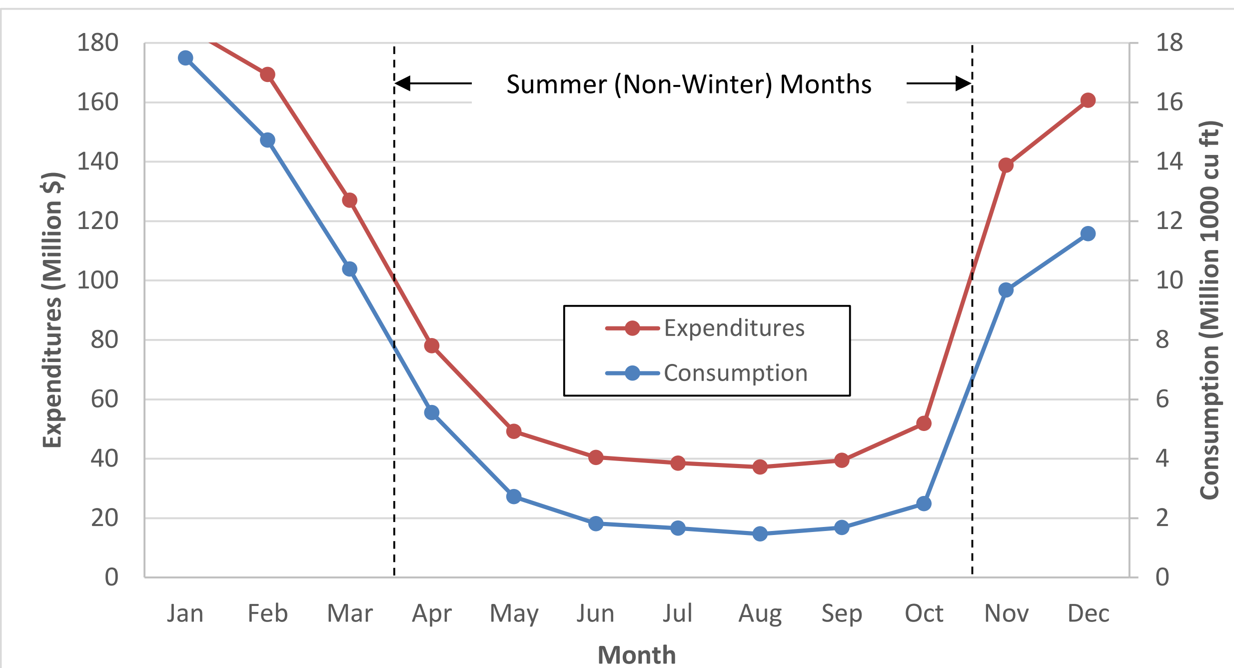

Figure 8E.4.2 2021 Monthly Residential Natural Gas Expenditures and Energy Use for Virginia

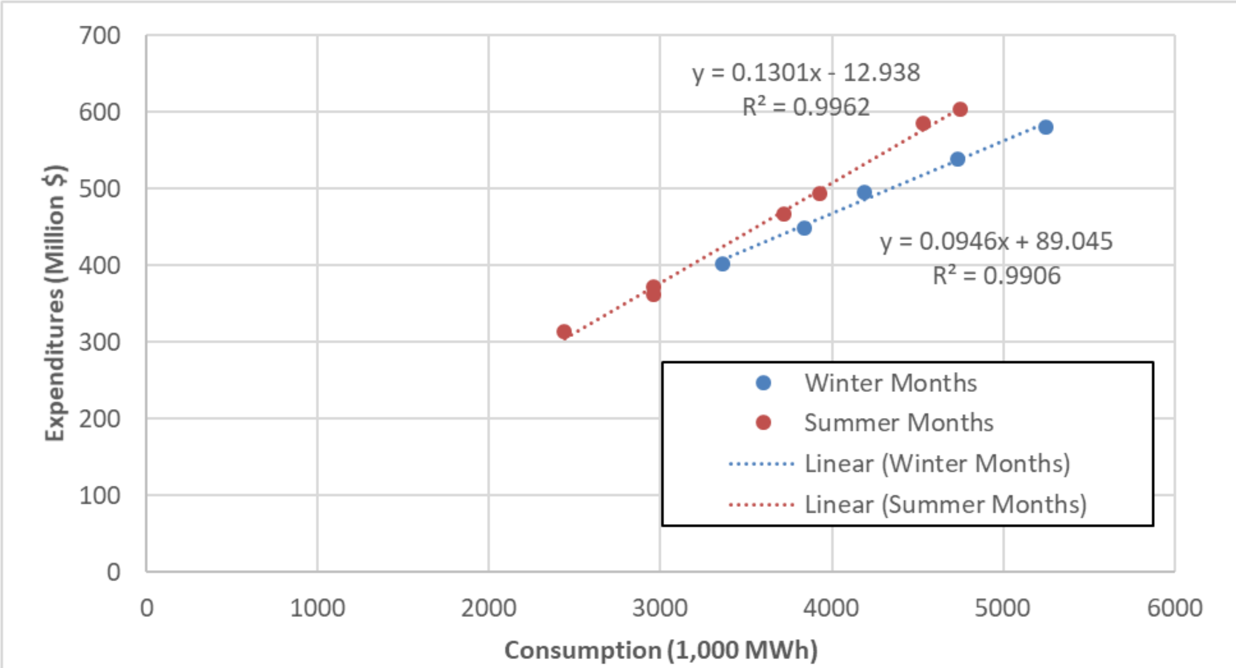

Figure 8E.4.3 Seasonal Linear Regression Analysis of 2021 Monthly Residential Electricty Expenditures and Energy Use for Virginia

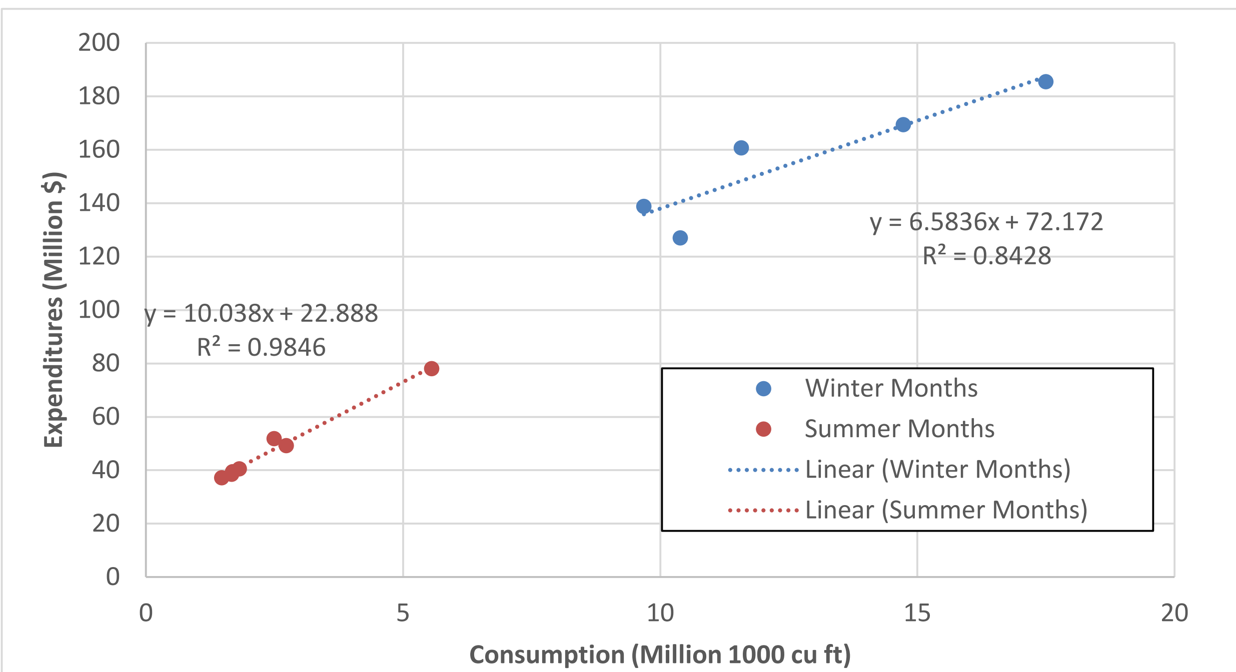

Figure 8E.4.4 Seasonal Linear Regression Analysis of 2021 Monthly Residential Natural Gas Expenditures and Energy Use for Virginia

Table 8E.4.1 Marginal Electricty Price Results (Residential) for Virginia using 2012-2021 EIA Data

Year	Summer (Non-Winter)				Winter			
	Electricity Price ($/kWh)		Marginal Price Factor	R-Squared for Linear Fit	Electricity Price ($/kWh)		Marginal Price Factor	R-Squared for Linear Fit
	Marginal	Average			Marginal	Average		
2012	0.115	0.114	1.01	0.99	0.091	0.107	0.85	0.99
2013	0.124	0.113	1.10	0.99	0.077	0.103	0.74	0.97
2014	0.130	0.117	1.12	0.99	0.076	0.105	0.72	0.96
2015	0.120	0.117	1.03	1.00	0.103	0.110	0.94	1.00
2016	0.116	0.117	0.99	0.99	0.094	0.109	0.86	1.00
2017	0.128	0.120	1.07	1.00	0.085	0.110	0.78	0.98
2018	0.131	0.121	1.08	1.00	0.097	0.112	0.86	1.00
2019	0.120	0.124	0.97	1.00	0.103	0.117	0.88	0.99
2020	0.120	0.123	0.98	1.00	0.101	0.117	0.86	0.98
2021	0.130	0.127	1.03	1.00	0.095	0.115	0.82	0.99
Average			1.04				0.83	

Table 8E.4.2 Marginal Natural Gas Price Results (Residential) for Virginia using 2012-2021 EIA Data

Year	Summer (Non-Winter)				Winter			
	Natural Gas Price ($/1000 cu ft)		Marginal Price Factor	R-Squared for Linear Fit	Natural Gas Price ($/1000 cu ft)		Marginal Price Factor	R-Squared for Linear Fit
	Marginal	Average			Marginal	Average		
2012	9.30	16.00	0.58	0.98	10.66	11.26	0.95	0.94
2013	9.14	15.49	0.59	0.98	9.59	10.61	0.90	0.89
2014	9.52	16.99	0.56	0.93	8.31	10.90	0.76	0.98
2015	8.44	16.29	0.52	0.89	8.83	10.47	0.84	0.97
2016	7.10	14.71	0.48	0.91	7.39	9.80	0.75	0.94
2017	10.53	18.37	--*	0.69	8.48	10.78	0.79	0.97
2018	8.57	15.31	0.56	0.94	8.70	10.70	0.81	0.94
2019	8.86	17.85	0.50	0.97	9.92	11.35	0.87	0.98
2020	8.63	15.36	0.56	0.91	10.24	11.84	0.86	0.96
2021	10.04	19.25	0.52	0.98	6.58	12.23	0.54	0.84
Average			0.54				0.81	

*The resulting marginal price factor is 0.57, but this value is excluded since r-squared for the linear regression is below 0.75.

8E.4.2 Results for the Seasonal Marginal Electricity and Natural Gas Price Factors

Table 8E.4.3 shows the resulting electricity and natural gas seasonal marginal price factors for both residential and commercial sectors by state.

Table 8E.4.3 Marginal Electricity and Natural Gas Price Factors, EIA 2012-2021 Data

State	Electricity				Natural Gas			
	Residential		Commercial		Residential		Commercial	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Alabama	0.98	0.82	1.03	0.74	0.65	0.86	0.91	0.96
Alaska	0.81	0.91	0.78	0.78	0.82	0.96	0.92	1.06
Arizona	1.01	0.87	1.24	0.94	0.60	0.76	0.96	0.88
Arkansas	1.04	0.79	1.08	0.88	0.56	0.85	0.75	1.01
California	1.27	0.96	1.86	0.87	0.88	1.08	0.97	1.20
Colorado	1.14	0.88	1.29	0.62	0.58	0.82	0.73	0.91
Connecticut	0.87	0.88	0.84	1.05	0.65	0.85	0.75	0.83
Delaware	0.82	0.78	0.77	0.81	0.56	0.83	0.76	0.89
District of Columbia	0.88	0.81	0.83	0.93	0.63	0.83	0.92	0.84
Florida	1.04	1.04	0.97	0.74	0.56	0.66	0.94	0.94
Georgia	1.18	0.87	1.15	1.00	0.77	0.77	0.85	0.93
Hawaii	0.88	0.92	0.93	1.00	1.20	0.83	1.17	1.16
Idaho	1.16	1.01	1.24	0.80	0.82	0.92	0.90	0.94
Illinois	0.84	0.69	0.95	0.70	0.49	0.84	0.37	1.00
Indiana	0.89	0.76	0.94	0.59	0.50	0.81	0.57	0.85
Iowa	1.28	0.81	1.83	0.77	0.53	0.83	0.63	0.97
Kansas	0.99	0.77	1.06	0.44	0.47	0.87	0.60	0.90
Kentucky	0.93	0.82	0.90	0.52	0.42	0.79	0.60	0.79
Louisiana	0.99	0.78	0.89	0.67	0.56	0.81	1.06	1.04
Maine	0.95	0.94	0.93	1.08	0.84	1.06	1.05	1.13
Maryland	0.92	0.92	0.87	1.08	0.59	0.81	0.73	0.81
Massachusetts	0.90	1.04	1.18	1.33	0.95	1.03	1.13	1.05
Michigan	1.05	0.91	1.10	0.71	0.69	0.88	0.73	0.93
Minnesota	1.10	0.87	1.32	0.71	0.66	0.96	0.85	1.06
Mississippi	0.89	0.77	0.89	0.81	0.58	0.81	1.05	0.93
Missouri	1.26	0.74	1.82	0.62	0.47	0.72	0.65	0.81
Montana	0.91	0.88	0.97	0.79	0.77	0.90	0.75	0.91
Nebraska	1.17	0.71	1.39	0.72	0.52	0.85	0.92	1.11
Nevada	0.92	0.82	1.02	0.70	0.59	0.80	0.78	0.91
New Hampshire	0.85	0.92	0.85	1.07	0.72	0.96	0.79	0.99
New Jersey	1.05	1.01	1.26	1.12	0.73	0.93	0.72	0.96
New Mexico	1.16	0.91	1.52	0.93	0.49	0.85	0.98	1.00
New York	1.06	0.93	1.52	1.09	0.59	0.80	1.32	1.16
North Carolina	0.94	0.82	1.14	0.62	0.58	0.82	0.87	0.96
North Dakota	0.81	0.73	0.86	0.68	0.45	0.84	0.79	1.13
Ohio	1.03	0.83	0.91	0.73	0.33	0.69	0.70	0.92
Oklahoma	0.92	0.63	1.27	1.05	0.44	0.71	0.57	0.65
Oregon	0.97	0.94	0.98	0.78	0.76	1.13	0.87	1.27
Pennsylvania	0.98	0.88	0.91	0.96	0.60	0.87	0.73	0.93
Rhode Island	0.85	1.02	0.87	0.95	0.74	0.83	0.75	0.82
South Carolina	0.96	0.83	1.08	0.71	0.46	0.77	1.02	1.12
South Dakota	0.99	0.79	1.20	0.75	0.63	0.84	0.76	0.97
Tennessee	0.97	0.86	1.10	0.71	0.51	0.86	0.83	1.07
Texas	0.97	0.86	0.89	0.53	0.46	0.70	0.67	0.91
Utah	1.15	0.97	1.14	0.46	0.84	0.95	0.98	0.99
Vermont	0.91	0.84	0.86	0.88	0.62	0.85	1.06	1.13
Virginia	1.04	0.83	1.04	1.03	0.54	0.81	0.78	0.90
Washington	0.88	0.95	0.94	0.91	0.77	0.93	0.85	0.97
West Virginia	0.91	0.82	0.72	0.72	0.67	0.90	0.62	0.92
Wisconsin	0.95	0.85	1.14	0.68	0.65	0.96	0.92	1.09
Wyoming	0.87	0.85	0.83	0.56	0.61	0.78	0.88	0.97
United States	1.04	0.83	1.24	0.73	0.57	0.87	0.81	0.98

8E.4.3 Comparison to Natural Gas Tariff Analysis

In the past, DOE received comment about the use of average natural gas prices. The Gas Technology Institute (GTI) commented that, because the monthly fixed charge contributes to the average price, marginal prices may generally be lower than average prices. As described above, DOE developed marginal price factors to account for this difference, but these factors were developed from EIA data, not directly from gas tariff documents. GTI submitted documents describing a total of 23 residential gas tariffs for 13 companies operating in multiple states.[11] DOE used this information to validate the residential natural gas marginal price factors presented in Table 8E.4.3.

8E.4.3.1 Calculation Methodology for Comparison

DOE used the following calculation approach to estimate the ratio of marginal to average prices, or the marginal price factors, for the 23 tariffs submitted by GTI.

Tariffs have one or more tiers. The simplest tariff structure consists of a monthly fixed cost (*FC*) and a commodity cost (*i.e.*, for units of gas) (*CC*). The total monthly bill (*MonthlyBill*) is:

$$MonthlyBill = FC + U \times CC$$

Eq. 8E.3

Where:

FC = monthly fixed cost for natural gas,
U = monthly consumer natural gas usage, and
CC = commodity cost for natural gas.

The average monthly price (*AveragePrice*) is equal to the ratio of the monthly bill to the total monthly usage:

$$AveragePrice = \frac{MonthlyBill}{U} = \frac{FC}{U} + CC$$

Eq. 8E.4

The marginal price is equal to the commodity cost *CC*; therefore, for this type of tariff, the average price exceeds the marginal price by the amount *FC*/*U*:

$$AveragePrice = MarginalPrice + \frac{FC}{U}$$

Eq. 8E.5

Where:

MarginalPrice = marginal price, which is equal to the commodity cost *CC*.

The difference between the average and marginal prices decreases with customer usage *U*, and thus should be larger in the summer, when usage is lower. For tariffs with multiple tiers, the difference depends on tier in which the customer is.

To determine the marginal price factors for each season (summer or winter) ($MarginalPriceFactor_{Season}$) for each of the 23 tariffs, DOE calculated the ratio of the average monthly natural gas price to the marginal price:

$$MarginalPriceFactor_{Season} = \frac{MarginalPrice_{Season}}{AveragePrice_{Season}}$$

Eq. 8E.6

Where:

Season = summer or winter.

8E.4.3.2 Data Inputs

DOE estimated the monthly usage *U* based on the RECS 2015 average annual natural gas consumption by RECS 2015 regions. DOE used monthly natural gas consumption data from EIA's Natural Gas Navigator to allocate natural gas usage to summer and winter months. These data show that on average 70 percent of annual consumption occurs in the winter (the 5 months from November through March) and 30 percent during the rest of the year (the remaining 7 months). Hence, DOE defined summer monthly usage as:

$$Summer\ Monthly\ NG\ Usage = \frac{30\%\ of\ Annual\ NG\ Usage}{7\ summer\ months/year} \times Annual\ Average\ NG\ Usage$$

Eq. 8E.7

and winter monthly usage as:

$$Winter\ Monthly\ NG\ Usage = \frac{70\%\ of\ Annual\ NG\ Usage}{5\ winter\ months/year} \times Annual\ Average\ NG\ Usage$$

Eq. 8E.8

DOE obtained the fixed charges and commodity charges from the tariff documents submitted by GTI. Of these 23 tariffs, eight have more than one tier. For the eight tariffs with multiple tiers, DOE estimated the commodity cost as the average of the two-tier charges.

8E.4.3.3 Comparison Results

Table 8E.4.4 lists the marginal price factors for each of the 23 tariffs submitted by GTI. It also includes the marginal price factors estimated from the EIA data (2012-2021) for comparison (see Table 8E.4.4), and the assumed monthly summer and winter natural gas usage in therms. The EIA data and usage estimates depend only on the region. In general, the tariff-based marginal price factors for winter are less than one, as expected.

The summer and winter price factors used by DOE are generally comparable to those computed from the tariff data, indicating that DOE's marginal price estimates are reasonable at average usage levels. Of the 23 tariffs analyzed, eight have multiple tiers, and of these eight, six have ascending rates and two have descending rates. Because this analysis uses an average of the two tiers as the commodity price, it will generally underestimate the marginal prices for consumers subject to the second tier.

A full tariff-based analysis would require information about the household's total baseline gas usage (to establish which tier the consumer is in), and a weight factor for each tariff that determines how many customers are served by that utility on that tariff. These data are generally not available in the public domain. DOE's use of EIA state-level data effectively averages over all consumer sales in each state, and so incorporates information about all utilities. DOE's approach is therefore more likely to provide prices representative of a typical consumer than any individual tariff.

Table 8E.4.4 Tariff-Based (GTI) and EIA Marginal Price Factors and Natural Gas Consumption by Season

State	Summer		Winter		Natural Gas Consumption *Therms*	
	GTI Tariff Data	EIA Data 2012-2021	GTI Tariff Data	EIA Data 2012-2021	Summer	Winter
Arizona	0.61	0.60	0.84	0.76	13	43
California	0.84	0.88	0.95	1.08	17	57
Colorado	0.70	0.58	0.88	0.82	35	116
Colorado	0.67	0.58	0.87	0.82	35	116
Colorado	0.69	0.58	0.88	0.82	35	116
Connecticut	0.54	0.65	0.79	0.85	33	109
Connecticut	0.59	0.65	0.82	0.85	33	109
Connecticut	0.74	0.65	0.90	0.85	33	109
Delaware	0.66	0.56	0.87	0.83	27	90
District of Columbia	0.60	0.63	0.83	0.83	27	90
Idaho	0.88	0.82	0.96	0.92	34	110
Idaho	0.85	0.82	0.94	0.92	34	110
Iowa	0.61	0.53	0.84	0.83	37	120
Kansas	0.56	0.47	0.81	0.87	33	107
Maryland	0.73	0.59	0.91	0.81	27	90
Maryland	0.73	0.59	0.90	0.81	27	90
Maryland	0.72	0.59	0.89	0.81	27	90
Minnesota	0.76	0.66	0.92	0.96	37	120
Nevada	0.68	0.59	0.87	0.80	23	74
Oregon	0.80	0.76	0.93	1.13	32	105
Pennsylvania	0.65	0.60	0.86	0.87	31	102
Virginia	0.70	0.54	0.89	0.81	28	90
Washington	0.76	0.77	0.91	0.93	32	105

8E.5 HOUSEHOLD ENERGY PRICE ADJUSTMENT FACTOR

Both RECS 2015 and CBECS 2012 report the total annual consumption and expenditure of each energy use type. From this data DOE determined average energy prices per geographical area. To take into account that household energy prices vary inside a state, DOE developed an adjustment factor based on the reported average energy price in RECS 2015 or CBECS 2012 divided by the average energy price of the state. This factor was then multiplied times the monthly marginal energy prices (for natural gas and electricity) or the monthly price developed above to come up with the household energy price.

8E.6 BASE YEAR AVERAGE & MARGINAL MONTHLY ENERGY PRICES

For electricity and natural gas, DOE applied the state monthly energy price factors presented in section 8E.3 to annual average prices presented in section 8E.2 to develop residential and commercial average monthly energy prices for 2020 as shown in Table 8E.6.1 through Table 8E.6.4. DOE then applied the marginal price factors presented in section 8E.4 to the monthly average energy prices to develop marginal residential and commercial monthly energy prices for 2021 as shown in Table 8E.6.5 through Table 8E.6.8.

For LPG, DOE applied the Census Region monthly energy price factors presented in section 8E.3 to the annual energy price data presented in section 8E.2 to develop residential and commercial monthly energy prices for 2021 as shown in Table 8E.6.9 through Table 8E.6.10.

The following equation summarizes DOE's approach of calculating the energy cost per year using monthly average and marginal energy prices together with monthly energy consumption for each sampled consumer pool heater:

$$EC_t = \left[\sum_m MEC_{BASE,t,m} \times MEP_{AVG,t,m} + \sum_m \Delta MEC_{t,m} \times MEP_{MAR,t,m} \times MEPF_{MAR,t,m}\right] \times EPT_t$$

Eq. 8E.9

Where:

$MEC_{BASE,t,m}$ = monthly energy consumption at the site for baseline design in the month *m* of year *t*,
$MEP_{AVG,t,m}$ = monthly average energy price in the month *m* of year *t*,
$\Delta MEC_{t,m}$ = change in monthly energy consumption from higher efficiency design in the month *m* of year *t*,
$MEP_{MAR,t,m}$ = monthly average marginal energy price in the month *m* of year *t*,
$MEPF_{MAR,t,m}$ = monthly marginal energy price factor for the month *m* of year *t*, and
EPT_t = energy price trend in year *t* (see section 8E.7).

Table 8E.6.1 Residential Average Monthly Electricity Prices for 2021 (2021$/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.122	0.126	0.129	0.134	0.132	0.135	0.134	0.135	0.135	0.135	0.131	0.123
Alaska	0.215	0.216	0.221	0.224	0.230	0.232	0.237	0.234	0.229	0.230	0.227	0.224
Arizona	0.113	0.116	0.118	0.124	0.135	0.133	0.132	0.131	0.131	0.130	0.119	0.117
Arkansas	0.102	0.107	0.109	0.114	0.116	0.118	0.118	0.118	0.119	0.114	0.114	0.107
California	0.230	0.227	0.224	0.208	0.228	0.237	0.239	0.240	0.234	0.207	0.233	0.233
Colorado	0.124	0.126	0.127	0.129	0.131	0.136	0.136	0.136	0.137	0.132	0.131	0.127
Connecticut	0.211	0.218	0.218	0.224	0.227	0.223	0.218	0.219	0.221	0.224	0.218	0.212
Delaware	0.116	0.118	0.120	0.125	0.133	0.132	0.128	0.129	0.130	0.135	0.131	0.123
District of Columbia	0.124	0.126	0.127	0.128	0.133	0.138	0.137	0.138	0.137	0.134	0.130	0.129
Florida	0.118	0.119	0.119	0.121	0.118	0.120	0.120	0.121	0.122	0.121	0.123	0.120
Georgia	0.115	0.118	0.122	0.124	0.127	0.135	0.137	0.138	0.133	0.125	0.121	0.114
Hawaii	0.322	0.325	0.325	0.328	0.330	0.334	0.335	0.336	0.337	0.338	0.339	0.338
Idaho	0.098	0.097	0.098	0.098	0.102	0.107	0.108	0.108	0.102	0.104	0.100	0.099
Illinois	0.122	0.127	0.132	0.138	0.142	0.137	0.134	0.135	0.136	0.140	0.136	0.125
Indiana	0.124	0.127	0.132	0.141	0.142	0.137	0.134	0.136	0.139	0.144	0.140	0.130
Iowa	0.112	0.115	0.119	0.126	0.132	0.137	0.141	0.142	0.135	0.128	0.122	0.116
Kansas	0.116	0.122	0.127	0.132	0.135	0.135	0.137	0.137	0.135	0.131	0.128	0.121
Kentucky	0.108	0.110	0.112	0.118	0.119	0.118	0.117	0.117	0.118	0.121	0.119	0.115
Louisiana	0.102	0.105	0.108	0.110	0.114	0.113	0.114	0.115	0.115	0.116	0.110	0.107
Maine	0.167	0.169	0.171	0.170	0.172	0.172	0.170	0.171	0.173	0.172	0.172	0.168
Maryland	0.124	0.125	0.126	0.129	0.133	0.139	0.137	0.137	0.137	0.136	0.130	0.129
Massachusetts	0.230	0.232	0.232	0.232	0.230	0.228	0.223	0.227	0.233	0.227	0.228	0.235
Michigan	0.168	0.169	0.169	0.172	0.176	0.181	0.182	0.183	0.179	0.177	0.174	0.173
Minnesota	0.125	0.127	0.128	0.131	0.136	0.143	0.143	0.142	0.140	0.137	0.132	0.129
Mississippi	0.110	0.112	0.117	0.122	0.123	0.121	0.119	0.119	0.118	0.119	0.121	0.115
Missouri	0.097	0.099	0.104	0.111	0.125	0.133	0.132	0.131	0.119	0.113	0.108	0.102
Montana	0.106	0.107	0.108	0.110	0.114	0.117	0.118	0.118	0.119	0.117	0.112	0.109
Nebraska	0.092	0.096	0.099	0.106	0.111	0.121	0.123	0.124	0.125	0.110	0.105	0.098
Nevada	0.114	0.118	0.119	0.120	0.118	0.115	0.113	0.113	0.116	0.120	0.122	0.117
New Hampshire	0.194	0.197	0.198	0.201	0.203	0.200	0.196	0.196	0.200	0.204	0.201	0.199
New Jersey	0.156	0.159	0.158	0.159	0.161	0.169	0.174	0.174	0.170	0.159	0.159	0.159
New Mexico	0.127	0.130	0.130	0.132	0.134	0.141	0.144	0.145	0.141	0.141	0.132	0.129
New York	0.185	0.189	0.186	0.188	0.195	0.201	0.202	0.201	0.203	0.200	0.194	0.188
North Carolina	0.107	0.112	0.113	0.118	0.117	0.115	0.116	0.117	0.120	0.122	0.116	0.110
North Dakota	0.093	0.096	0.099	0.106	0.116	0.126	0.123	0.124	0.126	0.115	0.106	0.099
Ohio	0.118	0.120	0.123	0.129	0.133	0.135	0.135	0.134	0.131	0.131	0.128	0.122
Oklahoma	0.103	0.120	0.116	0.126	0.123	0.125	0.125	0.126	0.133	0.131	0.119	0.106
Oregon	0.110	0.111	0.111	0.113	0.114	0.115	0.116	0.116	0.116	0.116	0.114	0.113
Pennsylvania	0.130	0.133	0.133	0.137	0.141	0.143	0.142	0.142	0.141	0.141	0.139	0.135
Rhode Island	0.224	0.229	0.225	0.223	0.221	0.218	0.213	0.223	0.232	0.224	0.228	0.235
South Carolina	0.125	0.128	0.129	0.136	0.134	0.134	0.133	0.133	0.135	0.136	0.135	0.129
South Dakota	0.110	0.112	0.114	0.120	0.127	0.132	0.131	0.130	0.133	0.130	0.122	0.116
Tennessee	0.107	0.107	0.110	0.113	0.115	0.113	0.112	0.112	0.111	0.115	0.116	0.113
Texas	0.115	0.117	0.119	0.122	0.123	0.124	0.123	0.123	0.123	0.122	0.121	0.119
Utah	0.099	0.100	0.100	0.101	0.105	0.109	0.112	0.112	0.108	0.103	0.101	0.101
Vermont	0.186	0.188	0.190	0.194	0.195	0.196	0.193	0.193	0.195	0.199	0.198	0.192
Virginia	0.112	0.115	0.117	0.123	0.126	0.128	0.128	0.128	0.127	0.124	0.121	0.115
Washington	0.098	0.099	0.099	0.100	0.101	0.103	0.103	0.103	0.104	0.103	0.102	0.101
West Virginia	0.115	0.117	0.120	0.124	0.127	0.126	0.123	0.124	0.126	0.129	0.125	0.119
Wisconsin	0.139	0.141	0.142	0.146	0.150	0.151	0.148	0.148	0.151	0.149	0.146	0.142
Wyoming	0.103	0.105	0.107	0.110	0.115	0.118	0.119	0.118	0.120	0.119	0.112	0.107
United States	0.129	0.131	0.134	0.137	0.140	0.141	0.142	0.142	0.142	0.139	0.138	0.133

Table 8E.6.2 Commercial Average Monthly Electricity Prices for 2021 (2021$/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.117	0.119	0.119	0.120	0.119	0.122	0.121	0.122	0.121	0.121	0.121	0.118
Alaska	0.189	0.190	0.193	0.196	0.200	0.200	0.201	0.198	0.197	0.198	0.196	0.195
Arizona	0.094	0.096	0.096	0.099	0.107	0.110	0.110	0.109	0.107	0.105	0.097	0.096
Arkansas	0.091	0.095	0.093	0.093	0.095	0.098	0.098	0.098	0.096	0.095	0.094	0.093
California	0.168	0.173	0.170	0.172	0.184	0.211	0.220	0.218	0.214	0.199	0.182	0.171
Colorado	0.099	0.103	0.104	0.107	0.108	0.114	0.113	0.113	0.113	0.110	0.109	0.105
Connecticut	0.166	0.171	0.167	0.169	0.169	0.168	0.167	0.168	0.167	0.167	0.166	0.165
Delaware	0.091	0.095	0.094	0.093	0.096	0.099	0.096	0.097	0.097	0.096	0.097	0.095
District of Columbia	0.124	0.128	0.126	0.127	0.131	0.134	0.131	0.132	0.136	0.131	0.129	0.128
Florida	0.094	0.098	0.096	0.096	0.094	0.094	0.094	0.095	0.095	0.096	0.098	0.097
Georgia	0.106	0.107	0.107	0.107	0.107	0.109	0.110	0.111	0.108	0.108	0.107	0.106
Hawaii	0.306	0.304	0.304	0.305	0.307	0.309	0.313	0.315	0.316	0.318	0.320	0.320
Idaho	0.076	0.077	0.078	0.079	0.079	0.083	0.081	0.081	0.078	0.080	0.079	0.076
Illinois	0.093	0.094	0.096	0.097	0.098	0.099	0.100	0.100	0.098	0.099	0.096	0.093
Indiana	0.112	0.115	0.116	0.118	0.117	0.116	0.116	0.117	0.117	0.118	0.118	0.116
Iowa	0.092	0.094	0.096	0.097	0.101	0.109	0.115	0.116	0.107	0.097	0.095	0.093
Kansas	0.097	0.101	0.104	0.105	0.107	0.110	0.110	0.110	0.108	0.105	0.102	0.099
Kentucky	0.103	0.107	0.106	0.109	0.109	0.109	0.108	0.109	0.110	0.108	0.110	0.109
Louisiana	0.100	0.103	0.104	0.103	0.103	0.102	0.103	0.103	0.103	0.105	0.103	0.103
Maine	0.133	0.139	0.134	0.125	0.125	0.125	0.125	0.125	0.128	0.128	0.133	0.136
Maryland	0.099	0.101	0.100	0.099	0.102	0.106	0.106	0.106	0.108	0.104	0.101	0.102
Massachusetts	0.169	0.173	0.170	0.166	0.163	0.174	0.176	0.177	0.180	0.170	0.165	0.172
Michigan	0.117	0.122	0.122	0.121	0.125	0.126	0.125	0.125	0.123	0.123	0.123	0.122
Minnesota	0.104	0.106	0.106	0.108	0.112	0.121	0.120	0.119	0.116	0.109	0.108	0.106
Mississippi	0.109	0.111	0.111	0.111	0.111	0.111	0.110	0.109	0.109	0.110	0.112	0.112
Missouri	0.080	0.081	0.083	0.084	0.097	0.108	0.108	0.107	0.094	0.085	0.084	0.082
Montana	0.102	0.104	0.105	0.105	0.107	0.107	0.107	0.107	0.109	0.109	0.107	0.105
Nebraska	0.081	0.084	0.085	0.085	0.088	0.094	0.095	0.095	0.095	0.087	0.085	0.084
Nevada	0.077	0.079	0.077	0.077	0.076	0.076	0.077	0.077	0.078	0.079	0.078	0.077
New Hampshire	0.161	0.165	0.163	0.163	0.163	0.162	0.160	0.160	0.162	0.163	0.162	0.164
New Jersey	0.122	0.122	0.123	0.123	0.127	0.139	0.139	0.141	0.135	0.123	0.122	0.122
New Mexico	0.102	0.105	0.104	0.103	0.105	0.112	0.114	0.115	0.111	0.110	0.106	0.105
New York	0.153	0.155	0.154	0.153	0.157	0.172	0.179	0.177	0.177	0.167	0.156	0.155
North Carolina	0.084	0.087	0.087	0.085	0.085	0.086	0.089	0.088	0.089	0.089	0.085	0.086
North Dakota	0.084	0.087	0.088	0.091	0.093	0.098	0.096	0.097	0.098	0.093	0.090	0.088
Ohio	0.094	0.097	0.098	0.099	0.099	0.098	0.098	0.098	0.099	0.099	0.099	0.095
Oklahoma	0.078	0.081	0.078	0.080	0.081	0.091	0.092	0.093	0.093	0.088	0.080	0.079
Oregon	0.089	0.091	0.091	0.092	0.091	0.091	0.090	0.089	0.089	0.092	0.091	0.090
Pennsylvania	0.087	0.089	0.089	0.090	0.090	0.090	0.089	0.089	0.089	0.089	0.090	0.088
Rhode Island	0.160	0.165	0.158	0.152	0.153	0.153	0.152	0.156	0.155	0.153	0.157	0.163
South Carolina	0.105	0.108	0.106	0.106	0.105	0.110	0.109	0.109	0.110	0.107	0.110	0.109
South Dakota	0.096	0.099	0.098	0.100	0.102	0.105	0.105	0.105	0.105	0.103	0.101	0.099
Tennessee	0.107	0.107	0.109	0.109	0.109	0.110	0.110	0.110	0.109	0.110	0.112	0.112
Texas	0.089	0.094	0.093	0.091	0.090	0.092	0.091	0.092	0.091	0.089	0.090	0.089
Utah	0.075	0.078	0.078	0.079	0.085	0.089	0.084	0.084	0.087	0.084	0.078	0.074
Vermont	0.163	0.164	0.165	0.167	0.169	0.168	0.166	0.164	0.167	0.169	0.168	0.166
Virginia	0.077	0.077	0.078	0.077	0.078	0.078	0.079	0.079	0.078	0.079	0.079	0.078
Washington	0.092	0.093	0.093	0.092	0.091	0.091	0.091	0.091	0.092	0.094	0.094	0.094
West Virginia	0.092	0.095	0.096	0.097	0.096	0.093	0.093	0.094	0.095	0.098	0.099	0.094
Wisconsin	0.105	0.108	0.106	0.109	0.110	0.113	0.112	0.112	0.113	0.109	0.109	0.106
Wyoming	0.092	0.094	0.095	0.097	0.099	0.100	0.098	0.097	0.099	0.100	0.098	0.092
United States	0.107	0.110	0.110	0.110	0.111	0.116	0.118	0.118	0.117	0.114	0.111	0.109

Table 8E.6.3 Residential Average Monthly Natural Gas Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	14.06	13.98	14.44	16.24	18.47	20.30	21.28	21.48	21.37	20.68	17.27	14.95
Alaska	10.27	10.38	10.23	10.52	11.20	11.95	12.87	12.63	11.49	10.68	10.28	10.66
Arizona	13.16	13.92	14.90	16.36	18.25	20.25	22.06	22.58	21.96	19.56	16.25	13.93
Arkansas	11.99	11.92	12.48	13.95	15.54	19.23	20.90	21.75	21.14	18.99	14.44	12.68
California	15.89	15.61	15.02	14.44	15.30	16.29	16.57	16.51	16.31	16.33	15.65	16.03
Colorado	8.33	8.36	8.82	9.12	10.59	13.42	14.82	14.97	13.18	9.94	8.90	8.50
Connecticut	14.98	15.07	15.39	16.42	18.39	20.93	23.00	23.81	23.34	19.90	16.53	15.58
Delaware	12.26	12.56	13.16	14.31	16.54	19.83	22.09	23.26	22.45	19.78	14.26	12.74
District of Columbia	14.99	14.67	15.20	16.21	18.47	20.36	22.20	21.82	21.62	19.03	16.64	15.15
Florida	19.42	19.43	20.71	21.96	22.75	25.90	27.39	28.05	27.44	27.04	24.48	21.37
Georgia	13.78	14.58	15.44	18.24	22.39	26.36	27.81	28.31	28.10	22.84	16.62	14.90
Hawaii	42.33	43.75	44.76	45.03	45.99	46.25	46.75	47.05	46.88	46.84	45.70	44.68
Idaho	6.92	6.94	7.13	7.25	7.56	8.10	8.54	8.70	8.10	7.37	6.92	6.83
Illinois	9.61	9.65	10.34	11.36	13.95	16.14	19.70	19.98	18.49	13.18	10.92	10.10
Indiana	8.96	9.09	10.12	11.55	13.42	16.41	18.35	18.05	15.17	10.90	9.18	8.98
Iowa	9.33	9.48	10.41	10.68	12.58	16.32	18.98	19.76	18.84	13.85	10.97	9.68
Kansas	10.15	10.36	10.95	13.15	15.66	19.42	21.06	22.35	20.77	16.08	11.35	10.45
Kentucky	11.46	11.47	12.00	13.86	17.36	21.99	23.74	24.45	23.27	17.11	12.93	12.08
Louisiana	10.72	10.74	11.53	12.88	13.95	15.41	16.93	17.21	16.69	16.37	13.16	11.01
Maine	14.40	14.87	14.74	15.13	15.06	15.99	17.90	18.55	17.57	15.61	14.60	14.99
Maryland	13.15	12.95	13.45	14.95	17.74	20.73	22.20	22.65	21.80	16.32	14.38	13.74
Massachusetts	15.25	15.17	15.19	15.58	15.70	15.49	17.02	17.74	17.16	14.75	15.25	15.77
Michigan	8.59	8.67	8.90	9.42	10.78	12.70	13.83	14.26	13.04	10.33	9.21	8.89
Minnesota	9.10	9.12	9.34	9.33	10.65	12.67	13.64	13.37	12.55	9.94	9.03	9.36
Mississippi	12.10	12.19	13.45	14.96	17.11	19.17	18.99	19.47	19.54	18.56	14.95	13.23
Missouri	9.65	9.64	10.16	11.95	14.60	19.29	22.56	23.63	22.12	18.16	12.66	10.62
Montana	8.57	8.64	8.70	8.99	9.45	10.69	12.29	13.16	11.92	9.69	8.93	8.69
Nebraska	9.24	9.39	9.62	10.57	12.10	14.72	17.58	18.52	17.92	14.89	11.26	10.04
Nevada	8.59	8.83	9.25	10.21	11.12	11.91	13.01	13.53	12.97	11.77	10.08	8.87
New Hampshire	15.64	15.50	15.58	16.31	16.95	18.22	21.69	23.03	22.31	19.08	16.57	16.74
New Jersey	9.87	9.80	9.82	9.91	10.91	12.00	12.63	13.01	12.68	11.60	10.63	10.10
New Mexico	8.57	8.56	8.79	9.50	10.87	13.36	14.89	14.55	15.13	13.43	10.31	8.66
New York	12.59	12.41	12.75	13.38	15.16	18.06	19.64	19.99	19.48	16.07	14.36	13.13
North Carolina	12.01	12.12	12.56	14.75	18.14	21.28	22.76	22.40	22.19	18.27	13.56	13.08
North Dakota	7.43	7.49	7.81	8.33	10.06	14.20	15.99	15.89	14.57	8.43	8.09	7.69
Ohio	10.94	11.07	11.33	12.67	15.79	20.59	24.77	25.93	24.14	16.92	12.66	11.59
Oklahoma	9.37	9.60	10.11	12.48	15.81	19.95	23.05	25.07	24.02	21.26	13.94	10.06
Oregon	11.18	11.12	11.40	11.80	12.64	13.52	14.65	15.62	14.52	12.54	11.00	11.13
Pennsylvania	11.02	11.11	11.36	12.06	13.79	16.89	18.89	19.57	18.51	14.73	12.12	11.40
Rhode Island	14.52	14.66	14.95	15.92	17.20	18.87	20.64	21.45	21.11	19.11	16.35	15.24
South Carolina	11.65	11.90	12.48	14.87	18.76	20.40	22.93	22.77	22.41	18.22	13.20	11.82
South Dakota	9.60	9.75	10.44	10.51	11.32	14.25	16.87	17.49	16.38	11.90	10.55	9.83
Tennessee	9.82	9.83	9.67	11.40	13.56	16.13	17.64	17.64	17.53	15.57	11.73	9.80
Texas	11.17	11.75	12.75	15.60	18.76	21.12	22.64	24.06	23.46	21.03	16.13	12.41
Utah	8.55	8.72	8.79	8.58	8.42	9.28	10.12	10.55	10.31	9.18	8.79	8.92
Vermont	13.34	13.08	13.36	13.80	15.20	18.10	20.80	21.86	21.10	17.89	14.95	13.96
Virginia	12.24	12.25	12.36	13.96	16.01	18.85	21.90	21.70	21.37	16.41	13.69	12.93
Washington	10.87	10.91	11.04	11.46	11.79	13.50	14.57	15.09	13.98	12.01	11.26	10.93
West Virginia	9.78	9.86	9.99	10.74	12.51	14.85	17.34	17.63	15.75	12.11	10.50	10.09
Wisconsin	9.84	9.79	10.33	9.86	11.39	13.10	15.03	15.36	13.96	10.18	10.41	10.06
Wyoming	9.69	9.83	10.00	10.37	11.20	13.59	17.94	19.03	17.09	12.79	10.71	9.97
United States	11.34	11.39	11.77	12.65	14.45	16.84	18.30	18.78	17.90	14.61	12.49	11.81

Table 8E.6.4 Commercial Average Monthly Natural Gas Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	11.20	11.20	11.27	11.76	11.88	12.01	12.07	12.15	12.35	12.28	12.02	11.57
Alaska	9.87	9.83	9.63	9.47	9.32	9.41	9.65	9.74	9.67	9.79	9.79	9.98
Arizona	8.36	8.48	8.61	8.62	8.79	8.73	8.77	8.79	8.81	8.79	8.59	8.39
Arkansas	8.42	8.37	8.49	8.78	8.82	9.62	9.68	9.68	9.43	9.02	9.09	8.78
California	12.44	12.03	11.83	10.85	10.50	11.27	11.58	11.47	11.21	11.28	11.93	12.75
Colorado	7.93	7.83	8.04	8.11	8.70	9.46	10.06	10.04	9.70	8.57	8.28	8.01
Connecticut	10.02	9.99	10.01	10.62	11.09	11.80	11.53	11.41	11.25	10.70	10.47	10.10
Delaware	9.96	10.20	10.60	11.10	11.76	12.37	12.88	12.99	12.73	12.22	10.65	10.11
District of Columbia	13.36	13.34	13.46	13.80	13.61	13.74	13.95	13.61	13.44	13.24	13.87	13.27
Florida	11.60	11.60	11.57	11.56	11.58	11.64	11.71	11.54	11.60	11.47	11.60	11.69
Georgia	7.45	7.53	7.75	8.27	8.76	9.12	9.21	9.26	9.05	8.64	7.48	7.38
Hawaii	30.17	31.31	32.19	32.26	32.85	33.62	31.81	33.36	33.36	33.69	32.73	32.23
Idaho	5.67	5.66	5.74	5.90	5.94	5.96	6.01	5.97	5.91	5.77	5.69	5.61
Illinois	8.10	8.12	8.22	9.32	10.61	12.08	13.73	13.05	12.75	9.90	8.44	8.50
Indiana	7.90	7.89	8.70	9.34	10.19	11.16	11.21	10.88	8.95	7.80	7.72	7.75
Iowa	8.25	8.34	8.80	8.40	9.17	10.11	10.63	10.69	10.22	8.36	8.72	8.64
Kansas	8.41	8.52	8.86	10.11	11.20	12.24	12.71	12.75	12.66	10.82	8.90	8.53
Kentucky	9.24	9.14	9.36	10.23	10.84	12.33	12.49	12.70	12.36	10.97	9.99	9.61
Louisiana	9.56	9.17	9.31	8.96	9.07	8.75	9.30	8.49	9.02	9.33	9.62	9.22
Maine	13.48	13.75	13.35	13.35	12.16	11.17	12.57	11.80	12.27	11.47	12.44	13.31
Maryland	11.51	11.43	11.49	11.69	12.36	12.67	12.69	12.64	12.67	11.48	11.84	11.85
Massachusetts	12.22	12.24	12.25	12.30	11.58	10.66	10.93	10.97	10.99	10.13	11.55	12.56
Michigan	7.65	7.69	7.82	7.92	8.48	9.26	9.63	9.68	9.38	8.37	8.00	7.88
Minnesota	7.26	7.23	7.40	7.09	7.34	7.83	7.97	7.79	7.56	6.39	6.87	7.41
Mississippi	9.81	10.06	10.23	9.57	9.85	9.51	9.52	8.83	9.42	10.20	10.36	10.17
Missouri	7.18	7.08	7.20	7.66	8.07	8.95	9.52	9.57	9.21	8.82	8.20	7.61
Montana	8.19	8.27	8.30	8.50	8.92	9.24	10.41	10.57	10.24	8.35	8.45	8.29
Nebraska	7.01	6.97	6.97	6.82	6.57	6.76	7.12	7.17	6.71	6.81	6.94	7.23
Nevada	6.27	6.31	6.37	6.46	6.61	6.63	6.87	6.99	6.89	6.75	6.54	6.30
New Hampshire	12.86	12.84	12.84	13.23	13.20	13.44	15.22	15.44	15.05	13.51	13.02	13.43
New Jersey	10.62	10.45	10.60	9.42	9.87	10.38	10.71	10.35	9.94	10.34	11.05	10.98
New Mexico	7.10	7.05	6.95	6.58	7.24	7.70	8.15	8.28	8.13	8.11	7.88	7.52
New York	8.18	8.14	8.18	7.83	7.61	7.39	7.04	6.83	6.59	7.43	7.80	8.22
North Carolina	8.81	8.67	8.65	9.10	9.40	9.61	9.91	9.51	9.52	9.36	9.46	8.97
North Dakota	6.36	6.23	6.34	6.14	6.55	7.29	7.23	7.07	6.59	5.68	6.43	6.42
Ohio	6.68	6.66	6.59	6.85	7.32	7.86	7.99	8.05	7.82	7.29	6.82	6.80
Oklahoma	7.45	7.53	7.80	9.21	10.86	12.60	13.60	14.41	13.79	13.18	10.25	7.90
Oregon	8.11	8.43	8.57	8.67	8.76	8.96	9.06	9.34	9.11	8.81	8.10	8.53
Pennsylvania	9.14	9.26	9.46	9.56	10.39	10.88	11.20	10.94	10.59	9.86	9.28	9.34
Rhode Island	12.06	12.22	12.39	13.00	13.97	15.65	16.84	17.29	17.00	15.61	13.49	12.74
South Carolina	9.73	9.49	9.29	9.33	9.00	9.30	9.38	8.73	9.17	9.35	9.88	9.71
South Dakota	8.06	8.10	8.51	7.61	8.25	8.63	9.66	9.82	9.27	7.99	8.18	8.23
Tennessee	8.46	8.38	7.93	8.54	8.75	9.08	9.42	9.10	9.35	8.86	9.03	8.25
Texas	7.57	7.97	7.94	8.17	8.52	8.82	8.97	8.98	9.06	8.54	8.84	8.50
Utah	7.18	7.27	7.28	6.91	6.51	6.78	7.17	7.37	7.28	6.96	7.12	7.46
Vermont	6.49	6.52	6.37	6.27	6.18	5.93	5.97	5.96	6.11	5.95	6.21	6.44
Virginia	8.76	8.75	8.52	8.76	9.10	9.57	9.51	8.93	9.52	8.93	8.74	9.02
Washington	8.53	8.97	8.95	9.07	8.85	9.59	9.87	10.02	9.70	9.25	9.09	8.98
West Virginia	7.63	7.68	7.73	8.15	8.88	9.65	9.79	9.87	9.48	8.64	7.98	7.80
Wisconsin	8.57	8.53	8.75	7.96	8.05	8.64	8.60	8.50	8.35	7.41	8.64	8.71
Wyoming	7.60	7.59	7.63	7.53	7.62	8.07	8.67	8.84	8.69	8.20	7.92	7.69
United States	8.55	8.54	8.67	8.72	8.96	9.26	9.38	9.31	9.20	8.84	8.77	8.77

Table 8E.6.5 Residential Marginal Monthly Electricity Prices for 2021, 2021$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.099	0.103	0.105	0.132	0.129	0.132	0.131	0.132	0.132	0.132	0.107	0.101
Alaska	0.196	0.197	0.202	0.182	0.187	0.189	0.193	0.190	0.186	0.187	0.207	0.204
Arizona	0.098	0.101	0.103	0.126	0.136	0.134	0.134	0.133	0.133	0.131	0.103	0.102
Arkansas	0.080	0.084	0.085	0.118	0.120	0.123	0.123	0.123	0.124	0.118	0.090	0.084
California	0.220	0.217	0.214	0.264	0.290	0.301	0.305	0.306	0.298	0.263	0.223	0.223
Colorado	0.109	0.111	0.112	0.148	0.150	0.155	0.156	0.156	0.157	0.151	0.116	0.113
Connecticut	0.186	0.192	0.193	0.194	0.196	0.193	0.189	0.189	0.192	0.194	0.192	0.187
Delaware	0.091	0.092	0.094	0.103	0.109	0.108	0.104	0.105	0.107	0.110	0.103	0.096
District of Columbia	0.101	0.103	0.103	0.113	0.117	0.121	0.120	0.121	0.120	0.118	0.106	0.105
Florida	0.123	0.125	0.124	0.126	0.123	0.125	0.125	0.126	0.127	0.126	0.128	0.125
Georgia	0.099	0.102	0.105	0.146	0.150	0.159	0.161	0.162	0.157	0.148	0.104	0.099
Hawaii	0.297	0.299	0.300	0.289	0.290	0.294	0.295	0.296	0.296	0.298	0.313	0.312
Idaho	0.098	0.098	0.098	0.114	0.119	0.125	0.126	0.125	0.119	0.121	0.101	0.100
Illinois	0.084	0.087	0.090	0.116	0.119	0.115	0.113	0.113	0.115	0.118	0.093	0.086
Indiana	0.094	0.097	0.101	0.126	0.127	0.122	0.120	0.121	0.124	0.129	0.107	0.100
Iowa	0.091	0.093	0.096	0.162	0.169	0.176	0.180	0.182	0.173	0.164	0.098	0.094
Kansas	0.089	0.094	0.097	0.131	0.133	0.134	0.135	0.135	0.133	0.130	0.098	0.093
Kentucky	0.088	0.090	0.091	0.110	0.111	0.109	0.108	0.109	0.109	0.113	0.097	0.094
Louisiana	0.079	0.081	0.084	0.109	0.113	0.112	0.113	0.114	0.114	0.115	0.085	0.083
Maine	0.158	0.160	0.161	0.161	0.163	0.163	0.161	0.162	0.164	0.163	0.162	0.159
Maryland	0.115	0.115	0.116	0.119	0.123	0.129	0.126	0.126	0.127	0.126	0.120	0.119
Massachusetts	0.239	0.241	0.241	0.208	0.207	0.204	0.200	0.203	0.209	0.204	0.237	0.244
Michigan	0.152	0.153	0.153	0.182	0.185	0.191	0.192	0.193	0.189	0.186	0.157	0.157
Minnesota	0.109	0.110	0.111	0.145	0.150	0.158	0.158	0.157	0.155	0.151	0.114	0.111
Mississippi	0.085	0.087	0.091	0.108	0.109	0.108	0.106	0.106	0.105	0.106	0.094	0.089
Missouri	0.072	0.073	0.077	0.140	0.158	0.167	0.166	0.165	0.150	0.142	0.081	0.076
Montana	0.093	0.094	0.095	0.100	0.104	0.107	0.108	0.108	0.109	0.106	0.099	0.096
Nebraska	0.065	0.068	0.071	0.124	0.130	0.142	0.145	0.145	0.146	0.130	0.075	0.069
Nevada	0.094	0.096	0.097	0.110	0.109	0.105	0.104	0.104	0.106	0.110	0.100	0.096
New Hampshire	0.178	0.181	0.182	0.170	0.172	0.169	0.166	0.165	0.169	0.173	0.185	0.183
New Jersey	0.158	0.160	0.160	0.167	0.169	0.177	0.182	0.182	0.178	0.167	0.160	0.161
New Mexico	0.116	0.118	0.118	0.153	0.155	0.164	0.166	0.168	0.164	0.163	0.120	0.118
New York	0.171	0.175	0.173	0.199	0.206	0.213	0.214	0.213	0.215	0.211	0.180	0.175
North Carolina	0.088	0.091	0.093	0.111	0.109	0.107	0.109	0.110	0.112	0.115	0.095	0.090
North Dakota	0.068	0.070	0.073	0.086	0.094	0.102	0.100	0.100	0.102	0.093	0.077	0.072
Ohio	0.098	0.100	0.102	0.134	0.138	0.140	0.139	0.139	0.135	0.135	0.107	0.102
Oklahoma	0.065	0.076	0.073	0.116	0.113	0.114	0.114	0.116	0.122	0.120	0.075	0.067
Oregon	0.103	0.104	0.104	0.109	0.111	0.112	0.113	0.112	0.113	0.112	0.107	0.105
Pennsylvania	0.115	0.117	0.118	0.134	0.138	0.140	0.139	0.139	0.138	0.138	0.122	0.119
Rhode Island	0.228	0.234	0.229	0.191	0.189	0.186	0.182	0.191	0.198	0.192	0.232	0.239
South Carolina	0.104	0.107	0.108	0.130	0.128	0.128	0.127	0.127	0.129	0.130	0.113	0.107
South Dakota	0.087	0.089	0.090	0.119	0.127	0.131	0.130	0.129	0.132	0.129	0.096	0.091
Tennessee	0.092	0.092	0.094	0.110	0.111	0.110	0.109	0.109	0.108	0.112	0.100	0.097
Texas	0.099	0.101	0.103	0.118	0.119	0.121	0.120	0.120	0.120	0.119	0.105	0.103
Utah	0.096	0.096	0.096	0.116	0.121	0.125	0.128	0.128	0.124	0.118	0.098	0.097
Vermont	0.157	0.159	0.160	0.176	0.177	0.178	0.175	0.175	0.177	0.181	0.167	0.162
Virginia	0.093	0.095	0.098	0.127	0.130	0.133	0.133	0.133	0.131	0.129	0.101	0.096
Washington	0.093	0.094	0.094	0.088	0.089	0.090	0.090	0.090	0.091	0.090	0.097	0.096
West Virginia	0.095	0.096	0.099	0.113	0.116	0.114	0.112	0.113	0.115	0.118	0.103	0.098
Wisconsin	0.118	0.120	0.121	0.139	0.143	0.143	0.141	0.141	0.144	0.142	0.124	0.120
Wyoming	0.088	0.090	0.091	0.096	0.100	0.103	0.104	0.102	0.104	0.103	0.096	0.092
United States	0.107	0.109	0.111	0.142	0.145	0.147	0.147	0.148	0.147	0.145	0.115	0.111

Table 8E.6.6 Commercial Marginal Monthly Electricity Prices for 2021, 2021$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.086	0.088	0.087	0.123	0.122	0.126	0.125	0.126	0.124	0.125	0.089	0.087
Alaska	0.148	0.149	0.151	0.153	0.156	0.156	0.157	0.154	0.153	0.155	0.154	0.153
Arizona	0.089	0.090	0.090	0.123	0.133	0.136	0.137	0.135	0.133	0.130	0.091	0.091
Arkansas	0.079	0.083	0.082	0.100	0.102	0.105	0.105	0.105	0.104	0.102	0.082	0.081
California	0.146	0.150	0.148	0.320	0.341	0.392	0.409	0.405	0.397	0.371	0.158	0.148
Colorado	0.062	0.064	0.064	0.138	0.139	0.147	0.145	0.145	0.145	0.141	0.068	0.065
Connecticut	0.174	0.179	0.175	0.142	0.141	0.141	0.140	0.141	0.141	0.140	0.174	0.174
Delaware	0.074	0.076	0.076	0.072	0.074	0.077	0.074	0.075	0.075	0.074	0.078	0.076
District of Columbia	0.116	0.119	0.117	0.106	0.110	0.112	0.110	0.110	0.113	0.109	0.120	0.119
Florida	0.070	0.073	0.072	0.092	0.091	0.091	0.091	0.091	0.092	0.093	0.073	0.072
Georgia	0.106	0.107	0.107	0.122	0.123	0.126	0.127	0.127	0.124	0.124	0.107	0.106
Hawaii	0.305	0.303	0.303	0.282	0.285	0.287	0.290	0.292	0.293	0.295	0.320	0.319
Idaho	0.060	0.062	0.062	0.097	0.098	0.103	0.100	0.101	0.097	0.098	0.063	0.061
Illinois	0.065	0.066	0.067	0.093	0.094	0.095	0.095	0.096	0.094	0.095	0.067	0.065
Indiana	0.066	0.068	0.069	0.111	0.110	0.109	0.109	0.110	0.110	0.111	0.070	0.069
Iowa	0.071	0.073	0.074	0.178	0.184	0.199	0.211	0.212	0.196	0.178	0.074	0.072
Kansas	0.043	0.044	0.046	0.111	0.113	0.117	0.117	0.117	0.114	0.112	0.045	0.043
Kentucky	0.054	0.056	0.056	0.097	0.097	0.098	0.097	0.098	0.098	0.097	0.058	0.057
Louisiana	0.066	0.068	0.069	0.092	0.092	0.091	0.092	0.092	0.092	0.093	0.069	0.069
Maine	0.144	0.150	0.145	0.116	0.116	0.116	0.116	0.116	0.119	0.119	0.144	0.147
Maryland	0.107	0.109	0.107	0.086	0.088	0.092	0.092	0.092	0.094	0.090	0.109	0.110
Massachusetts	0.225	0.230	0.226	0.196	0.193	0.205	0.208	0.208	0.212	0.200	0.219	0.228
Michigan	0.083	0.087	0.086	0.133	0.137	0.138	0.137	0.137	0.135	0.135	0.087	0.087
Minnesota	0.073	0.075	0.075	0.143	0.148	0.160	0.159	0.158	0.154	0.145	0.077	0.075
Mississippi	0.089	0.090	0.090	0.099	0.099	0.099	0.098	0.097	0.097	0.098	0.091	0.091
Missouri	0.049	0.051	0.051	0.153	0.177	0.196	0.197	0.196	0.171	0.155	0.052	0.051
Montana	0.080	0.082	0.082	0.101	0.103	0.104	0.104	0.103	0.105	0.105	0.085	0.083
Nebraska	0.059	0.060	0.062	0.118	0.122	0.131	0.132	0.132	0.132	0.121	0.061	0.061
Nevada	0.054	0.056	0.054	0.079	0.078	0.077	0.078	0.079	0.080	0.080	0.055	0.054
New Hampshire	0.173	0.177	0.175	0.139	0.139	0.138	0.137	0.136	0.138	0.139	0.173	0.175
New Jersey	0.137	0.138	0.138	0.154	0.160	0.175	0.175	0.177	0.170	0.155	0.137	0.137
New Mexico	0.095	0.097	0.096	0.157	0.161	0.171	0.173	0.175	0.169	0.167	0.098	0.097
New York	0.167	0.170	0.168	0.233	0.240	0.262	0.273	0.269	0.269	0.255	0.170	0.169
North Carolina	0.052	0.054	0.054	0.097	0.097	0.098	0.101	0.101	0.101	0.101	0.053	0.054
North Dakota	0.057	0.059	0.060	0.078	0.080	0.084	0.083	0.084	0.085	0.080	0.061	0.060
Ohio	0.069	0.071	0.072	0.090	0.090	0.089	0.089	0.089	0.090	0.090	0.073	0.070
Oklahoma	0.083	0.085	0.082	0.101	0.103	0.115	0.117	0.118	0.118	0.112	0.084	0.083
Oregon	0.069	0.071	0.071	0.089	0.089	0.088	0.088	0.087	0.087	0.090	0.071	0.070
Pennsylvania	0.084	0.086	0.086	0.082	0.082	0.082	0.082	0.081	0.081	0.081	0.086	0.085
Rhode Island	0.151	0.157	0.150	0.133	0.133	0.133	0.132	0.135	0.135	0.133	0.149	0.154
South Carolina	0.074	0.076	0.075	0.115	0.114	0.119	0.118	0.117	0.118	0.115	0.078	0.077
South Dakota	0.072	0.074	0.073	0.119	0.122	0.125	0.126	0.126	0.126	0.123	0.076	0.074
Tennessee	0.077	0.077	0.078	0.120	0.120	0.122	0.121	0.121	0.120	0.121	0.080	0.080
Texas	0.047	0.050	0.049	0.081	0.080	0.082	0.081	0.081	0.080	0.079	0.047	0.047
Utah	0.035	0.036	0.036	0.090	0.097	0.101	0.096	0.096	0.099	0.096	0.036	0.034
Vermont	0.143	0.143	0.145	0.143	0.145	0.144	0.143	0.141	0.143	0.145	0.147	0.146
Virginia	0.079	0.080	0.080	0.080	0.081	0.082	0.082	0.082	0.082	0.082	0.081	0.081
Washington	0.084	0.085	0.085	0.086	0.086	0.086	0.086	0.085	0.087	0.088	0.086	0.086
West Virginia	0.066	0.069	0.069	0.070	0.069	0.067	0.067	0.068	0.068	0.070	0.071	0.068
Wisconsin	0.071	0.073	0.072	0.124	0.126	0.129	0.129	0.128	0.129	0.125	0.074	0.072
Wyoming	0.051	0.053	0.053	0.081	0.082	0.083	0.081	0.081	0.082	0.083	0.054	0.051
United States	0.079	0.081	0.081	0.136	0.138	0.144	0.146	0.145	0.144	0.141	0.082	0.080

Table 8E.6.7 Residential Marginal Monthly Natural Gas Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	12.11	12.05	12.44	10.54	11.99	13.18	13.82	13.95	13.87	13.43	14.89	12.88
Alaska	9.88	9.98	9.84	8.57	9.13	9.74	10.49	10.30	9.37	8.70	9.89	10.26
Arizona	10.06	10.65	11.39	9.87	11.00	12.21	13.30	13.62	13.24	11.80	12.43	10.65
Arkansas	10.16	10.10	10.58	7.78	8.67	10.73	11.66	12.14	11.79	10.59	12.24	10.74
California	17.16	16.86	16.22	12.67	13.43	14.30	14.55	14.49	14.32	14.34	16.90	17.31
Colorado	6.82	6.85	7.23	5.31	6.16	7.81	8.63	8.71	7.67	5.78	7.29	6.96
Connecticut	12.68	12.76	13.02	10.64	11.92	13.57	14.91	15.43	15.13	12.90	13.99	13.18
Delaware	10.21	10.46	10.96	7.97	9.22	11.05	12.31	12.96	12.51	11.02	11.88	10.61
District of Columbia	12.48	12.22	12.65	10.22	11.64	12.83	13.99	13.75	13.62	11.99	13.85	12.62
Florida	12.75	12.77	13.60	12.26	12.70	14.45	15.29	15.65	15.31	15.09	16.08	14.04
Georgia	10.67	11.30	11.96	14.03	17.22	20.27	21.39	21.77	21.61	17.57	12.88	11.54
Hawaii	35.02	36.19	37.03	54.04	55.19	55.50	56.10	56.46	56.26	56.20	37.80	36.96
Idaho	6.40	6.42	6.59	5.94	6.20	6.64	7.00	7.14	6.65	6.05	6.40	6.32
Illinois	8.10	8.13	8.71	5.59	6.87	7.94	9.69	9.84	9.10	6.49	9.20	8.51
Indiana	7.29	7.39	8.23	5.82	6.77	8.27	9.25	9.10	7.65	5.49	7.46	7.31
Iowa	7.73	7.86	8.63	5.61	6.61	8.58	9.97	10.39	9.90	7.28	9.10	8.03
Kansas	8.85	9.03	9.54	6.20	7.39	9.16	9.93	10.54	9.80	7.59	9.89	9.11
Kentucky	9.07	9.08	9.50	5.85	7.33	9.29	10.03	10.33	9.83	7.23	10.23	9.56
Louisiana	8.66	8.68	9.31	7.27	7.87	8.70	9.56	9.71	9.42	9.24	10.63	8.90
Maine	15.20	15.70	15.57	12.70	12.64	13.42	15.02	15.57	14.75	13.10	15.42	15.83
Maryland	10.62	10.46	10.87	8.86	10.51	12.29	13.15	13.42	12.92	9.67	11.62	11.10
Massachusetts	15.67	15.58	15.60	14.74	14.85	14.65	16.10	16.78	16.23	13.95	15.66	16.20
Michigan	7.58	7.65	7.85	6.47	7.40	8.72	9.50	9.79	8.96	7.09	8.12	7.85
Minnesota	8.78	8.80	9.01	6.15	7.02	8.36	9.00	8.82	8.28	6.55	8.71	9.03
Mississippi	9.82	9.90	10.92	8.64	9.88	11.08	10.97	11.25	11.29	10.72	12.14	10.74
Missouri	6.90	6.89	7.27	5.67	6.92	9.15	10.70	11.20	10.48	8.61	9.06	7.60
Montana	7.67	7.74	7.79	6.92	7.27	8.22	9.45	10.12	9.17	7.45	8.00	7.78
Nebraska	7.88	8.02	8.21	5.47	6.26	7.62	9.10	9.59	9.28	7.71	9.61	8.57
Nevada	6.87	7.06	7.40	5.98	6.51	6.97	7.62	7.92	7.59	6.89	8.06	7.10
New Hampshire	14.99	14.86	14.93	11.77	12.23	13.15	15.65	16.61	16.10	13.76	15.88	16.04
New Jersey	9.15	9.09	9.11	7.27	8.00	8.79	9.26	9.54	9.29	8.50	9.87	9.37
New Mexico	7.33	7.32	7.51	4.68	5.36	6.58	7.34	7.17	7.46	6.62	8.81	7.41
New York	10.06	9.91	10.18	7.89	8.94	10.65	11.58	11.78	11.49	9.47	11.47	10.49
North Carolina	9.79	9.88	10.24	8.49	10.44	12.25	13.10	12.89	12.77	10.52	11.05	10.66
North Dakota	6.25	6.30	6.57	3.79	4.58	6.45	7.27	7.22	6.63	3.83	6.80	6.47
Ohio	7.59	7.68	7.86	4.14	5.17	6.74	8.10	8.48	7.90	5.54	8.79	8.05
Oklahoma	6.68	6.84	7.21	5.53	7.01	8.84	10.21	11.11	10.64	9.42	9.94	7.17
Oregon	12.64	12.58	12.89	8.93	9.56	10.23	11.08	11.81	10.98	9.49	12.44	12.59
Pennsylvania	9.62	9.70	9.92	7.28	8.33	10.20	11.41	11.82	11.18	8.89	10.58	9.95
Rhode Island	12.12	12.23	12.47	11.82	12.76	14.00	15.32	15.92	15.67	14.18	13.64	12.71
South Carolina	8.96	9.15	9.59	6.90	8.71	9.47	10.64	10.57	10.40	8.46	10.14	9.08
South Dakota	8.07	8.21	8.78	6.64	7.15	9.01	10.66	11.05	10.35	7.52	8.88	8.27
Tennessee	8.46	8.46	8.32	5.84	6.94	8.26	9.04	9.04	8.98	7.98	10.10	8.44
Texas	7.86	8.26	8.96	7.20	8.66	9.75	10.45	11.11	10.83	9.71	11.34	8.73
Utah	8.11	8.28	8.34	7.24	7.11	7.83	8.54	8.90	8.70	7.74	8.34	8.46
Vermont	11.29	11.07	11.30	8.52	9.39	11.18	12.84	13.50	13.03	11.05	12.65	11.81
Virginia	9.90	9.91	10.00	7.59	8.71	10.25	11.91	11.80	11.62	8.92	11.07	10.46
Washington	10.08	10.12	10.24	8.82	9.08	10.39	11.21	11.62	10.76	9.24	10.45	10.14
West Virginia	8.77	8.84	8.95	7.21	8.40	9.97	11.63	11.83	10.57	8.12	9.41	9.05
Wisconsin	9.45	9.40	9.92	6.43	7.43	8.55	9.80	10.02	9.11	6.64	9.99	9.66
Wyoming	7.54	7.64	7.78	6.30	6.81	8.26	10.91	11.57	10.39	7.77	8.33	7.75
United States	9.81	9.85	10.18	7.18	8.20	9.55	10.38	10.65	10.15	8.29	10.81	10.22

Table 8E.6.8 Commercial Marginal Monthly Natural Gas Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	10.74	10.74	10.81	10.75	10.86	10.97	11.03	11.10	11.28	11.22	11.52	11.09
Alaska	10.45	10.41	10.19	8.67	8.53	8.61	8.84	8.92	8.85	8.96	10.36	10.56
Arizona	7.33	7.43	7.55	8.28	8.44	8.38	8.43	8.45	8.46	8.44	7.53	7.36
Arkansas	8.52	8.47	8.59	6.59	6.61	7.22	7.26	7.26	7.07	6.76	9.20	8.88
California	14.93	14.44	14.20	10.52	10.18	10.92	11.22	11.12	10.87	10.93	14.33	15.31
Colorado	7.21	7.12	7.31	5.89	6.32	6.87	7.31	7.29	7.05	6.23	7.53	7.29
Connecticut	8.34	8.32	8.34	8.01	8.36	8.90	8.70	8.61	8.49	8.07	8.72	8.42
Delaware	8.89	9.11	9.46	8.42	8.92	9.39	9.77	9.86	9.66	9.27	9.50	9.03
District of Columbia	11.17	11.15	11.25	12.64	12.47	12.59	12.78	12.47	12.31	12.13	11.59	11.09
Florida	10.90	10.91	10.88	10.85	10.87	10.93	11.00	10.84	10.89	10.77	10.91	10.99
Georgia	6.95	7.03	7.23	7.02	7.43	7.74	7.81	7.86	7.68	7.34	6.98	6.89
Hawaii	34.97	36.30	37.31	37.68	38.37	39.28	37.16	38.98	38.97	39.36	37.95	37.36
Idaho	5.33	5.32	5.40	5.33	5.37	5.38	5.43	5.39	5.34	5.21	5.35	5.27
Illinois	8.13	8.14	8.25	3.45	3.93	4.48	5.09	4.83	4.72	3.67	8.47	8.53
Indiana	6.74	6.72	7.42	5.28	5.76	6.31	6.34	6.15	5.06	4.41	6.58	6.60
Iowa	8.01	8.09	8.54	5.31	5.79	6.39	6.72	6.75	6.45	5.28	8.47	8.39
Kansas	7.60	7.70	8.01	6.02	6.67	7.29	7.57	7.59	7.54	6.44	8.05	7.71
Kentucky	7.32	7.24	7.41	6.11	6.48	7.36	7.46	7.59	7.38	6.55	7.92	7.61
Louisiana	9.97	9.56	9.71	9.46	9.57	9.24	9.82	8.97	9.52	9.85	10.03	9.61
Maine	15.27	15.57	15.12	13.99	12.74	11.70	13.17	12.36	12.86	12.01	14.09	15.08
Maryland	9.27	9.20	9.25	8.54	9.04	9.26	9.27	9.23	9.26	8.39	9.54	9.54
Massachusetts	12.88	12.91	12.91	13.88	13.06	12.03	12.33	12.37	12.39	11.43	12.18	13.24
Michigan	7.09	7.13	7.25	5.81	6.22	6.79	7.07	7.10	6.88	6.14	7.41	7.30
Minnesota	7.67	7.63	7.81	6.02	6.23	6.64	6.76	6.61	6.41	5.42	7.25	7.82
Mississippi	9.10	9.34	9.50	10.05	10.35	9.99	10.00	9.27	9.89	10.71	9.62	9.44
Missouri	5.84	5.76	5.86	4.95	5.21	5.78	6.15	6.18	5.95	5.70	6.68	6.19
Montana	7.47	7.54	7.57	6.38	6.69	6.93	7.81	7.93	7.68	6.26	7.70	7.56
Nebraska	7.77	7.72	7.73	6.30	6.07	6.24	6.57	6.63	6.20	6.29	7.69	8.02
Nevada	5.72	5.76	5.81	5.06	5.18	5.19	5.39	5.48	5.40	5.29	5.97	5.75
New Hampshire	12.75	12.73	12.74	10.47	10.45	10.64	12.05	12.22	11.91	10.70	12.91	13.32
New Jersey	10.24	10.07	10.22	6.75	7.07	7.43	7.67	7.41	7.12	7.40	10.66	10.59
New Mexico	7.12	7.08	6.98	6.46	7.11	7.56	8.00	8.12	7.98	7.96	7.90	7.54
New York	9.49	9.44	9.49	10.35	10.06	9.76	9.30	9.03	8.70	9.82	9.06	9.54
North Carolina	8.45	8.32	8.30	7.91	8.17	8.36	8.62	8.27	8.28	8.14	9.08	8.61
North Dakota	7.21	7.07	7.19	4.85	5.18	5.77	5.72	5.59	5.21	4.49	7.29	7.28
Ohio	6.12	6.10	6.04	4.81	5.14	5.52	5.61	5.65	5.49	5.12	6.25	6.23
Oklahoma	4.84	4.89	5.07	5.25	6.19	7.18	7.75	8.21	7.86	7.52	6.66	5.13
Oregon	10.28	10.69	10.86	7.58	7.66	7.83	7.92	8.16	7.96	7.70	10.27	10.81
Pennsylvania	8.47	8.58	8.78	7.01	7.62	7.98	8.21	8.03	7.77	7.23	8.61	8.66
Rhode Island	9.90	10.04	10.17	9.71	10.43	11.69	12.58	12.92	12.69	11.66	11.08	10.47
South Carolina	10.90	10.64	10.41	9.50	9.16	9.47	9.55	8.89	9.33	9.51	11.07	10.88
South Dakota	7.79	7.83	8.22	5.79	6.28	6.56	7.35	7.47	7.06	6.08	7.91	7.96
Tennessee	9.02	8.94	8.45	7.09	7.27	7.54	7.82	7.56	7.76	7.36	9.63	8.80
Texas	6.85	7.21	7.19	5.49	5.73	5.93	6.03	6.04	6.09	5.74	8.00	7.69
Utah	7.11	7.20	7.21	6.74	6.35	6.61	7.00	7.19	7.10	6.79	7.05	7.39
Vermont	7.36	7.39	7.22	6.65	6.56	6.29	6.34	6.33	6.48	6.32	7.04	7.31
Virginia	7.92	7.91	7.71	6.82	7.08	7.45	7.40	6.95	7.41	6.95	7.90	8.16
Washington	8.24	8.67	8.65	7.70	7.51	8.14	8.38	8.51	8.23	7.85	8.78	8.68
West Virginia	6.99	7.04	7.09	5.06	5.52	6.00	6.08	6.13	5.89	5.37	7.32	7.15
Wisconsin	9.32	9.28	9.52	7.35	7.43	7.98	7.94	7.85	7.70	6.84	9.40	9.47
Wyoming	7.35	7.34	7.38	6.65	6.73	7.12	7.65	7.80	7.67	7.24	7.66	7.44
United States	8.41	8.40	8.53	7.07	7.27	7.51	7.61	7.55	7.46	7.17	8.63	8.63

Table 8E.6.9 Residential Monthly LPG Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	23.64	23.71	23.35	22.90	22.54	22.11	21.61	21.20	21.73	22.63	23.33	24.09
Alaska	28.53	28.59	28.10	27.46	26.80	26.03	25.09	24.77	25.75	27.29	28.17	29.27
Arizona	26.13	26.18	25.73	25.14	24.54	23.84	22.98	22.69	23.58	25.00	25.80	26.80
Arkansas	22.60	22.67	22.32	21.89	21.55	21.14	20.66	20.27	20.77	21.64	22.31	23.03
California	26.36	26.41	25.96	25.37	24.76	24.05	23.18	22.89	23.79	25.22	26.03	27.04
Colorado	19.95	19.98	19.64	19.19	18.73	18.19	17.54	17.32	18.00	19.08	19.69	20.46
Connecticut	25.85	26.11	26.26	26.27	26.68	26.94	27.03	26.86	26.84	26.96	26.69	26.67
Delaware	21.75	21.82	21.49	21.07	20.74	20.35	19.88	19.51	20.00	20.83	21.47	22.17
District of Columbia	24.58	24.66	24.29	23.82	23.44	23.00	22.48	22.05	22.60	23.54	24.27	25.06
Florida	29.45	29.54	29.10	28.53	28.08	27.55	26.92	26.41	27.07	28.20	29.07	30.02
Georgia	22.29	22.36	22.02	21.60	21.26	20.86	20.38	20.00	20.49	21.35	22.01	22.72
Hawaii	44.20	44.28	43.52	42.53	41.51	40.32	38.87	38.38	39.89	42.28	43.64	45.34
Idaho	21.70	21.74	21.37	20.88	20.38	19.79	19.08	18.84	19.59	20.76	21.42	22.26
Illinois	17.49	17.48	17.27	17.00	16.79	16.20	15.72	15.67	16.04	16.51	17.26	18.03
Indiana	21.22	21.22	20.96	20.64	20.38	19.67	19.08	19.02	19.46	20.04	20.95	21.88
Iowa	16.04	16.04	15.84	15.60	15.41	14.87	14.42	14.38	14.71	15.15	15.84	16.54
Kansas	18.54	18.54	18.31	18.03	17.81	17.18	16.67	16.62	17.01	17.51	18.31	19.12
Kentucky	23.10	23.17	22.82	22.38	22.02	21.61	21.11	20.72	21.23	22.11	22.80	23.54
Louisiana	26.29	26.37	25.97	25.47	25.07	24.60	24.03	23.58	24.17	25.17	25.95	26.80
Maine	22.27	22.50	22.62	22.64	22.99	23.21	23.29	23.14	23.13	23.23	23.00	22.98
Maryland	24.31	24.39	24.02	23.56	23.18	22.75	22.23	21.81	22.35	23.28	24.00	24.78
Massachusetts	27.09	27.37	27.52	27.54	27.96	28.23	28.33	28.15	28.13	28.26	27.97	27.95
Michigan	20.30	20.29	20.04	19.73	19.49	18.80	18.24	18.19	18.61	19.16	20.03	20.92
Minnesota	19.22	19.22	18.99	18.69	18.46	17.81	17.28	17.23	17.63	18.15	18.98	19.82
Mississippi	25.05	25.13	24.75	24.27	23.89	23.44	22.90	22.47	23.03	23.99	24.73	25.54
Missouri	19.47	19.46	19.23	18.93	18.69	18.04	17.50	17.45	17.85	18.38	19.22	20.07
Montana	18.27	18.30	17.99	17.58	17.16	16.67	16.06	15.86	16.49	17.48	18.04	18.74
Nebraska	16.65	16.64	16.44	16.18	15.98	15.42	14.96	14.92	15.27	15.72	16.43	17.16
Nevada	25.78	25.83	25.39	24.81	24.21	23.52	22.67	22.39	23.27	24.66	25.45	26.45
New Hampshire	22.30	22.53	22.65	22.66	23.01	23.24	23.32	23.17	23.15	23.26	23.02	23.01
New Jersey	28.57	28.86	29.02	29.04	29.48	29.77	29.87	29.69	29.66	29.80	29.50	29.48
New Mexico	22.58	22.62	22.23	21.73	21.21	20.60	19.86	19.61	20.38	21.60	22.29	23.16
New York	24.87	25.12	25.26	25.27	25.66	25.91	26.00	25.84	25.82	25.93	25.67	25.66
North Carolina	23.74	23.81	23.45	23.00	22.63	22.21	21.70	21.29	21.82	22.73	23.43	24.19
North Dakota	17.44	17.44	17.23	16.96	16.75	16.16	15.68	15.63	15.99	16.47	17.22	17.98
Ohio	24.54	24.53	24.24	23.86	23.57	22.74	22.06	22.00	22.51	23.17	24.23	25.30
Oklahoma	17.75	17.81	17.54	17.20	16.93	16.61	16.23	15.92	16.32	17.00	17.53	18.10
Oregon	24.21	24.26	23.84	23.30	22.74	22.09	21.29	21.03	21.86	23.16	23.91	24.84
Pennsylvania	21.68	21.91	22.02	22.04	22.38	22.60	22.67	22.53	22.51	22.62	22.39	22.37
Rhode Island	27.22	27.50	27.64	27.66	28.09	28.36	28.46	28.28	28.26	28.39	28.10	28.08
South Carolina	25.14	25.21	24.83	24.35	23.97	23.52	22.98	22.55	23.11	24.07	24.81	25.62
South Dakota	18.53	18.53	18.30	18.02	17.80	17.17	16.66	16.61	16.99	17.50	18.29	19.10
Tennessee	22.28	22.35	22.02	21.59	21.25	20.85	20.37	19.99	20.49	21.34	22.00	22.71
Texas	24.64	24.72	24.35	23.87	23.50	23.06	22.53	22.10	22.65	23.59	24.33	25.12
Utah	20.72	20.76	20.40	19.94	19.46	18.90	18.22	17.99	18.70	19.82	20.46	21.25
Vermont	21.99	22.22	22.34	22.35	22.69	22.92	22.99	22.85	22.83	22.94	22.71	22.69
Virginia	24.70	24.77	24.40	23.93	23.55	23.11	22.58	22.15	22.71	23.65	24.38	25.17
Washington	22.69	22.73	22.34	21.83	21.31	20.70	19.95	19.70	20.48	21.70	22.40	23.28
West Virginia	24.95	25.03	24.65	24.18	23.79	23.35	22.81	22.38	22.94	23.89	24.63	25.43
Wisconsin	16.95	16.95	16.74	16.48	16.28	15.71	15.24	15.19	15.55	16.01	16.74	17.48
Wyoming	19.90	19.94	19.60	19.15	18.69	18.16	17.50	17.28	17.96	19.04	19.65	20.42
United States	22.46	22.60	22.45	22.29	22.31	21.86	20.88	20.40	21.02	21.70	22.40	23.08

Table 8E.6.10 Commercial Monthly LPG Prices for 2021, 2021$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	19.33	19.39	19.10	18.73	18.44	18.09	17.68	17.34	17.77	18.51	19.09	19.71
Alaska	20.13	20.16	19.82	19.37	18.90	18.36	17.70	17.48	18.17	19.25	19.87	20.65
Arizona	23.86	23.90	23.49	22.96	22.40	21.76	20.98	20.71	21.53	22.82	23.55	24.47
Arkansas	19.30	19.36	19.07	18.70	18.41	18.06	17.65	17.32	17.75	18.48	19.06	19.68
California	21.58	21.62	21.25	20.77	20.27	19.69	18.98	18.74	19.48	20.65	21.31	22.14
Colorado	17.16	17.19	16.89	16.51	16.11	15.65	15.09	14.90	15.48	16.41	16.94	17.60
Connecticut	18.88	19.07	19.17	19.19	19.48	19.67	19.74	19.61	19.60	19.69	19.49	19.48
Delaware	20.30	20.37	20.06	19.67	19.36	19.00	18.56	18.21	18.67	19.44	20.04	20.69
District of Columbia	21.53	21.60	21.27	20.86	20.53	20.15	19.68	19.31	19.80	20.62	21.26	21.95
Florida	20.26	20.32	20.01	19.63	19.32	18.95	18.52	18.17	18.62	19.40	20.00	20.65
Georgia	19.87	19.93	19.63	19.25	18.95	18.59	18.17	17.83	18.27	19.03	19.62	20.26
Hawaii	20.93	20.96	20.61	20.14	19.65	19.09	18.40	18.17	18.89	20.02	20.66	21.47
Idaho	17.67	17.70	17.40	17.00	16.59	16.12	15.54	15.34	15.95	16.90	17.44	18.12
Illinois	18.04	18.04	17.82	17.54	17.32	16.72	16.22	16.17	16.55	17.03	17.81	18.60
Indiana	18.18	18.17	17.95	17.67	17.45	16.84	16.34	16.29	16.67	17.16	17.94	18.74
Iowa	17.25	17.25	17.04	16.77	16.57	15.98	15.51	15.46	15.82	16.29	17.03	17.78
Kansas	17.33	17.33	17.12	16.85	16.64	16.06	15.58	15.53	15.89	16.36	17.11	17.87
Kentucky	18.69	18.75	18.47	18.11	17.82	17.49	17.09	16.77	17.18	17.90	18.45	19.05
Louisiana	18.93	18.99	18.71	18.34	18.05	17.71	17.31	16.98	17.41	18.13	18.69	19.30
Maine	18.73	18.92	19.02	19.04	19.33	19.52	19.58	19.46	19.45	19.53	19.34	19.32
Maryland	21.53	21.60	21.27	20.86	20.53	20.15	19.68	19.31	19.80	20.62	21.26	21.95
Massachusetts	18.86	19.06	19.16	19.17	19.47	19.66	19.72	19.60	19.59	19.67	19.48	19.46
Michigan	18.01	18.00	17.78	17.51	17.29	16.69	16.19	16.14	16.51	17.00	17.78	18.56
Minnesota	17.40	17.39	17.18	16.91	16.70	16.12	15.64	15.59	15.95	16.43	17.17	17.93
Mississippi	19.89	19.95	19.65	19.27	18.97	18.61	18.18	17.84	18.29	19.04	19.64	20.27
Missouri	16.96	16.96	16.75	16.49	16.29	15.72	15.25	15.20	15.56	16.02	16.75	17.49
Montana	16.67	16.71	16.42	16.04	15.66	15.21	14.66	14.48	15.05	15.95	16.46	17.10
Nebraska	17.17	17.17	16.96	16.70	16.49	15.91	15.44	15.39	15.75	16.21	16.95	17.70
Nevada	24.15	24.19	23.78	23.23	22.68	22.03	21.23	20.97	21.79	23.10	23.84	24.77
New Hampshire	17.75	17.93	18.03	18.04	18.32	18.50	18.56	18.45	18.43	18.52	18.33	18.32
New Jersey	19.91	20.11	20.22	20.23	20.55	20.75	20.82	20.69	20.67	20.76	20.56	20.54
New Mexico	18.05	18.09	17.78	17.37	16.95	16.47	15.87	15.68	16.29	17.27	17.82	18.52
New York	19.41	19.61	19.71	19.73	20.03	20.23	20.30	20.17	20.15	20.24	20.04	20.03
North Carolina	20.02	20.08	19.78	19.39	19.09	18.73	18.30	17.95	18.40	19.17	19.76	20.40
North Dakota	17.09	17.09	16.88	16.62	16.41	15.84	15.36	15.32	15.67	16.14	16.87	17.62
Ohio	17.96	17.95	17.74	17.46	17.24	16.64	16.14	16.09	16.47	16.96	17.73	18.51
Oklahoma	17.97	18.02	17.75	17.41	17.13	16.81	16.43	16.12	16.52	17.20	17.74	18.31
Oregon	20.13	20.16	19.82	19.37	18.90	18.36	17.70	17.48	18.17	19.25	19.87	20.65
Pennsylvania	19.79	19.99	20.10	20.11	20.42	20.63	20.69	20.56	20.55	20.64	20.43	20.42
Rhode Island	19.00	19.19	19.30	19.31	19.60	19.80	19.86	19.74	19.73	19.81	19.61	19.60
South Carolina	20.26	20.32	20.01	19.63	19.32	18.95	18.52	18.17	18.62	19.40	20.00	20.65
South Dakota	17.01	17.01	16.80	16.54	16.34	15.76	15.29	15.25	15.60	16.06	16.79	17.54
Tennessee	18.87	18.92	18.64	18.28	17.99	17.65	17.25	16.92	17.34	18.06	18.62	19.23
Texas	19.25	19.31	19.02	18.65	18.36	18.01	17.60	17.27	17.70	18.44	19.01	19.62
Utah	17.68	17.72	17.41	17.02	16.61	16.13	15.55	15.36	15.96	16.92	17.46	18.14
Vermont	18.82	19.02	19.12	19.13	19.42	19.62	19.68	19.56	19.54	19.63	19.43	19.42
Virginia	20.11	20.17	19.87	19.49	19.18	18.82	18.39	18.04	18.49	19.26	19.86	20.50
Washington	21.44	21.48	21.11	20.63	20.13	19.56	18.85	18.62	19.35	20.51	21.17	21.99
West Virginia	20.26	20.32	20.01	19.63	19.32	18.95	18.52	18.17	18.62	19.40	20.00	20.65
Wisconsin	17.84	17.84	17.62	17.35	17.13	16.53	16.04	15.99	16.36	16.85	17.61	18.39
Wyoming	17.33	17.36	17.07	16.68	16.28	15.81	15.24	15.05	15.64	16.58	17.11	17.78
United States	19.24	19.36	19.23	19.10	19.12	18.73	17.89	17.48	18.01	18.59	19.19	19.77

8E.7 ENERGY PRICE TRENDS

DOE used AEO 2022 Reference Case scenarios for the nine census divisions. DOE applied the projected energy price for each of the nine census divisions to each household or buliding in the sample based on the household's or building's location.

To project prices in future years, DOE multiplied the prices described in the preceding section by the forecast of annual average price changes in EIA's AEO 2022. DOE converted the forecasted energy prices into energy price factors, with 2021 as the base year. Figure 8E.7.1 shows the national residential and commercial price factor trends. Figure 8E.7.2 through Figure 8E.7.7 show the residential and commercial regional energy price factor trends, disaggregated by the nine census divisions.

To project price trends after 2050, DOE used simple extrapolations of the average annual growth rate in prices from 2046 to 2050 based on the methods used in the 2022 Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP).[12]

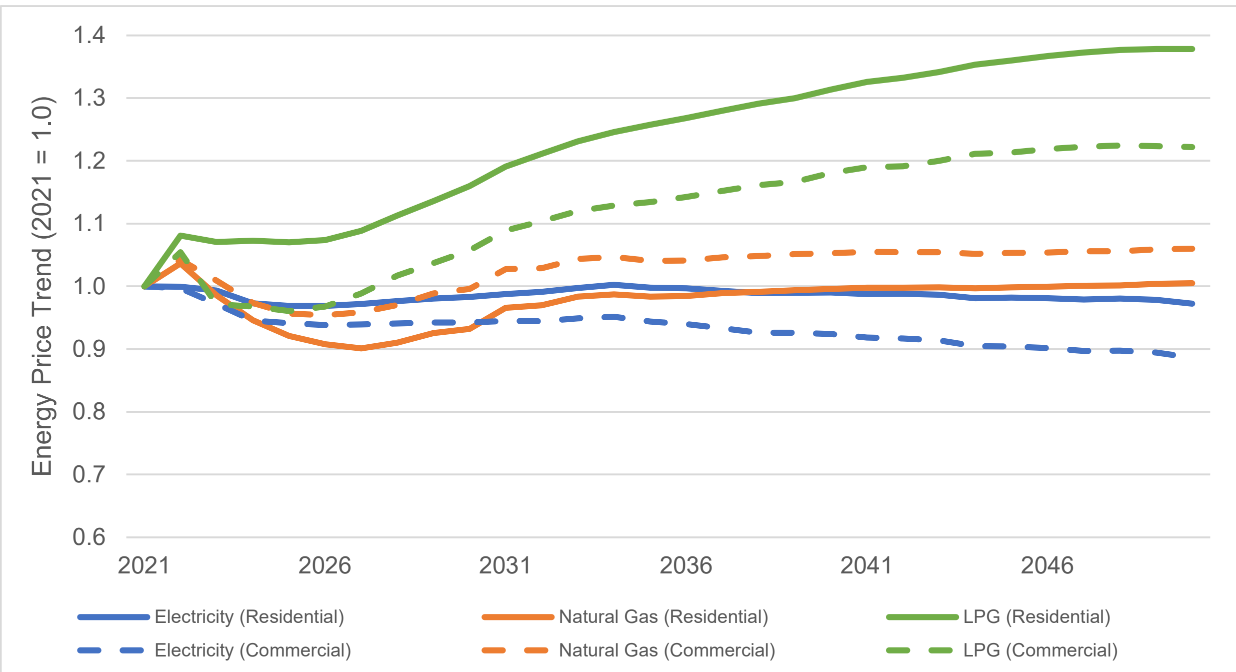

Figure 8E.7.1 Projected National Residential and Commercial Price Factors

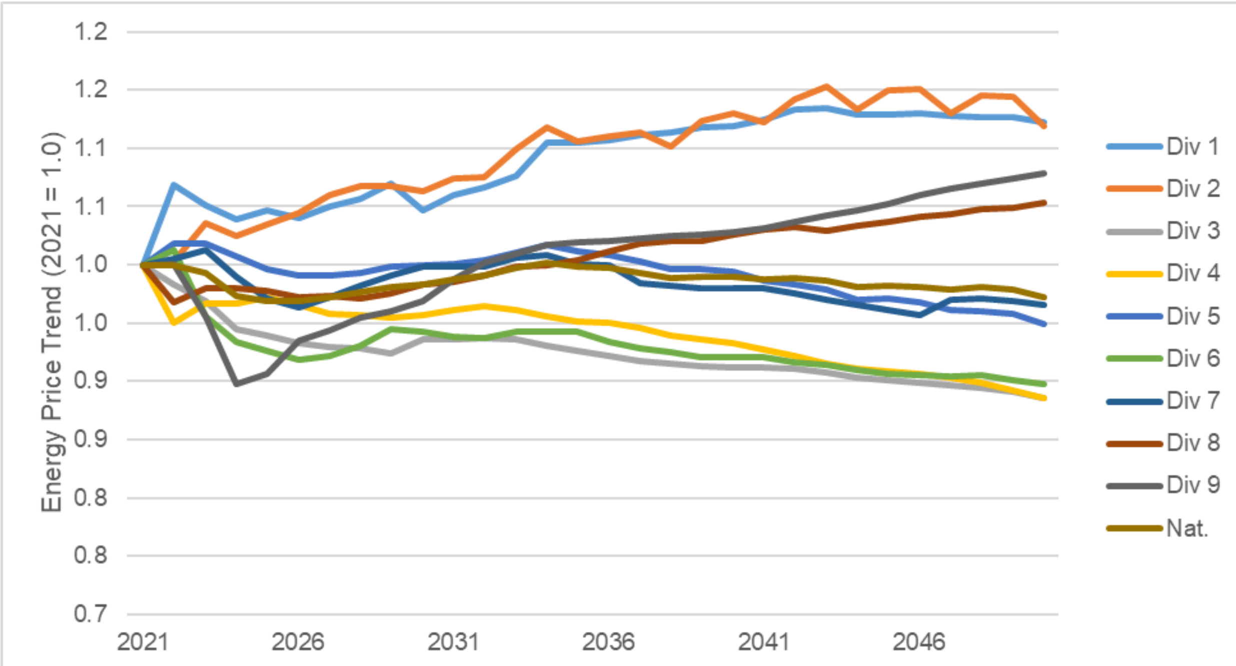

Figure 8E.7.2 Projected Residential Electricity Price Factors by Census Division

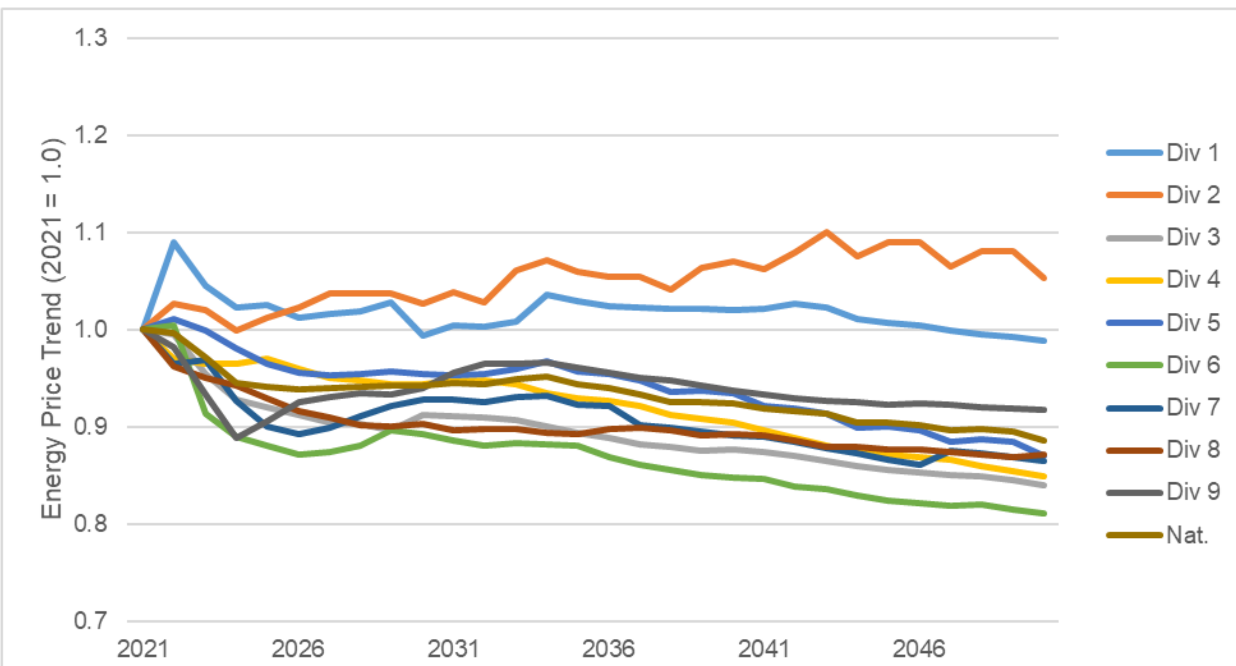

Figure 8E.7.3 Projected Commercial Electricity Price Factors by Census Division

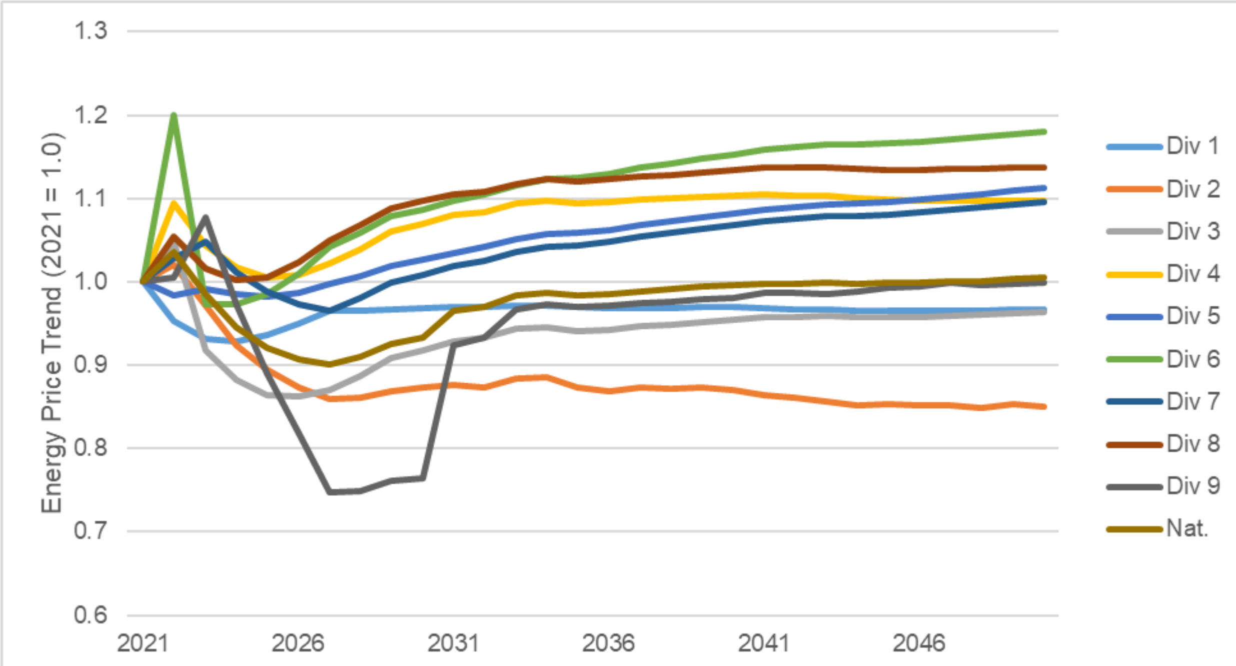

Figure 8E.7.4 Projected Residential Natural Gas Price Factors by Census Division

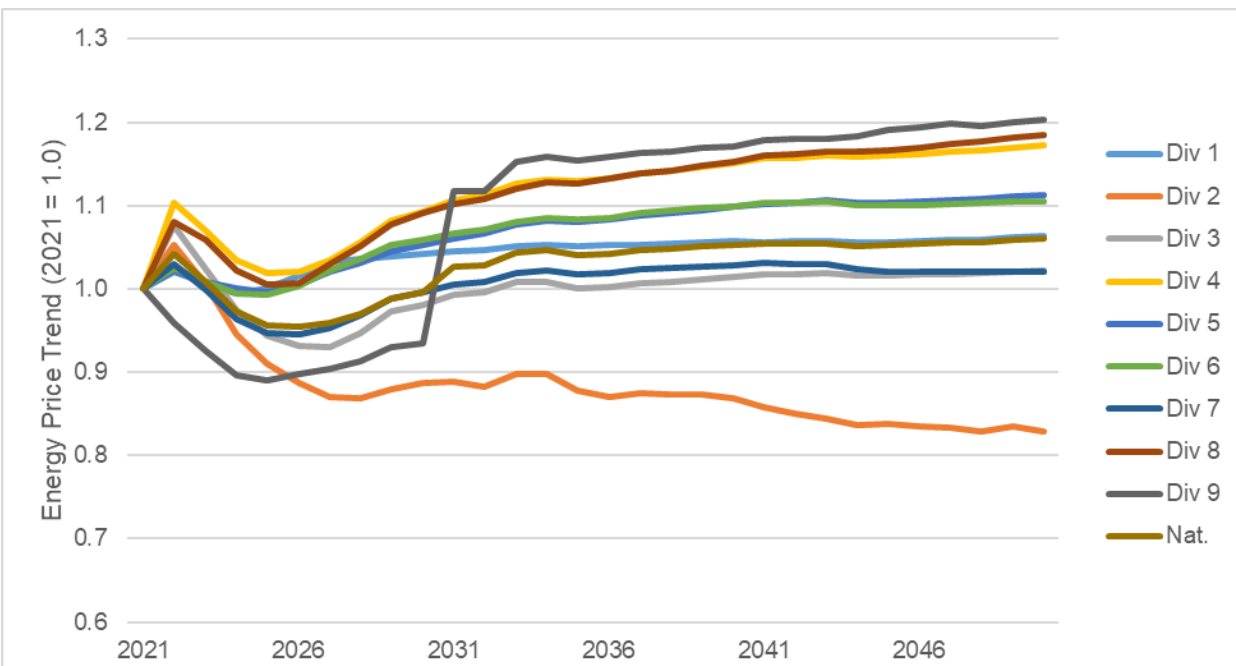

Figure 8E.7.5 Projected Commercial Natural Gas Price Factors by Census Division

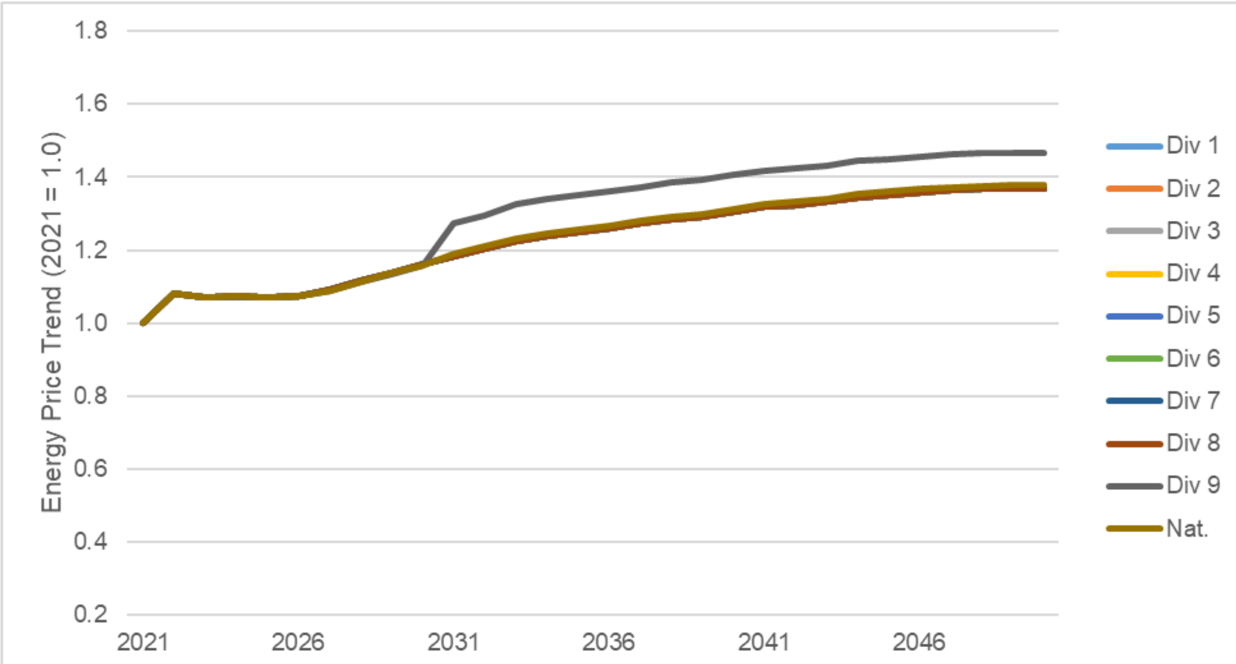

Figure 8E.7.6 Projected Residential LPG Price Factors by Census Division

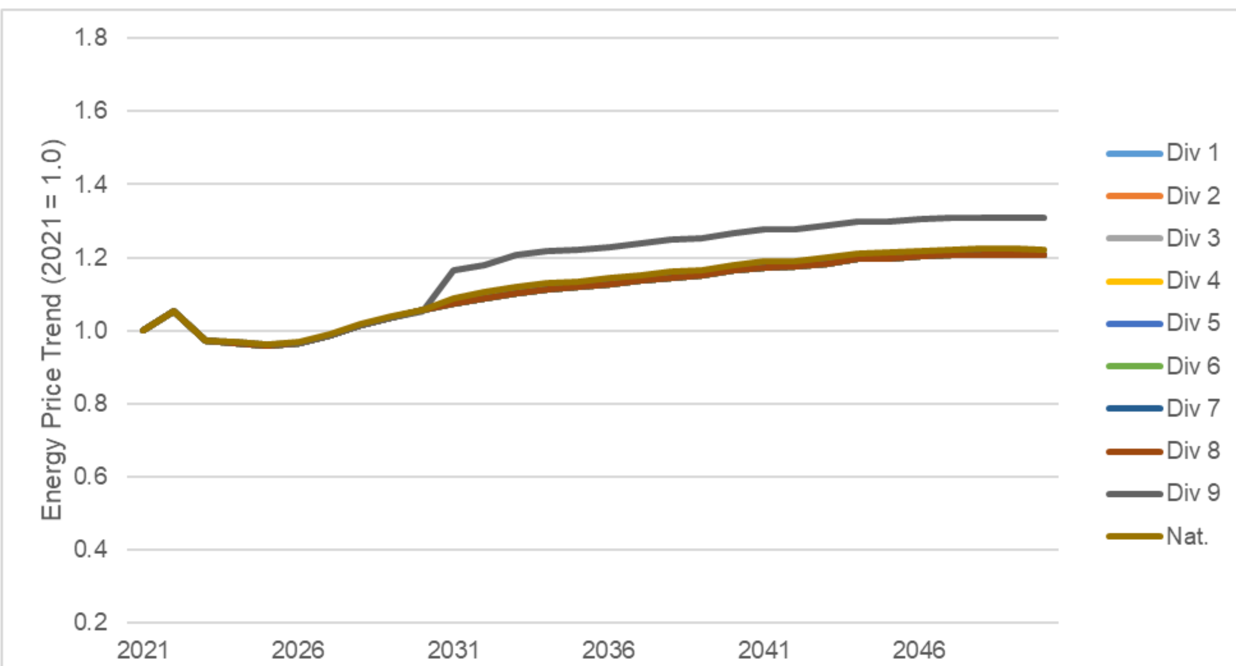

Figure 8E.7.7 Projected Commercial LPG Price Factors by Census Division

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APPENDIX 8F. MAINTENANCE AND REPAIR COST DETERMINATION FOR POOL HEATERS

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APPENDIX 8F. MAINTENANCE AND REPAIR COST DETERMINATION FOR POOL HEATERS

8F.1 INTRODUCTION

This appendix provides further details about the derivation of maintenance and repair costs for pool heaters.

The Department of Energy (DOE) estimated maintenance and repair costs for pool heaters based on RSMeans, a well-known and respected construction cost estimation method, as well as manufacturer literature and information from expert consultants. Table 8F.1.1 offers an example of the cost calculation method. All labor costs are derived using the 2021 RSMeans Residential Repair and Remodeling labor costs by crew type. Maintenance and repair cost tables include a trip charge, which is often charged by contractors and calculated to be equal to one half hour of labor per crew member. Labor hours (or person-hours) are based on RSMeans data and expert data. Bare costs are all the costs without any markups. Material costs are based on RSMeans data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RSMeans. Values reported in this appendix are based on national average labor costs. The labor costs shown in the tables in this appendix are the national average values. In its analysis, DOE used regional labor costs to more accurately estimate maintenance costs by region. Sections 8F.2 and 8F.3 discuss the maintenance and repair costs for pool heaters, respectively. Section 8F.4 describes the derivation of regional labor costs. DOE then applied the appropriate regional labor cost to each RECS sample household. The total costs include O&P.

Table 8F.1.1 Example Cost Table

Description	Crew	Labor Hours	Unit	Bare Costs *(2021$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	CREW1	0.5	-	0.00	23.00	23.00	1	35.00
Description of Installation Item	CREW1	0.5	Ea.	15.00	23.00	48.00	1	51.50
Total		1.0		15.00	46.00	71.00		**86.50**

8F.2 MAINTENANCE Cost for Pool Heaters

The maintenance cost is the routine annual cost to the consumer of general maintenance for product operation. DOE estimated maintenance costs at each considered efficiency level using a variety of sources, including *2021 RSMeans Facilities Repair and Maintenance Data*,[1] manufacturer literature, and information from expert consultants.[2] DOE determined that pool heaters typically go through some regular maintenance schedule.

8F.2.1 Maintenance Frequency

Maintenance frequency is based on consumer survey data for similar products and consultant interactions. The frequency with which the maintenance occurs for pool heaters was derived based on about how often air source heat pump (space heating and cooling) owners perform maintenance. RECS 2015 data[3] data shows that about 50 percent of air source heat pump owners perform regular maintenance on their appliance. The frequency with which the maintenance occurs is derived from a 2008 consumer survey on the frequency with which owners of different types of central air conditioning perform maintenance.[4] From this data, DOE assumed 60 percent perform maintenance every year, 20 percent perform maintenance every two years, and 20 percent perform maintenance every 5 years. The maintenance is usually conducted by the pool service contractor who performs other maintenance tasks associated with the swimming pool or spa (including cleaning the pool, maintaining chemical levels, pool pump service, etc.).

8F.2.2 Maintenance Costs

DOE assumed that maintenance costs for different technologies varied by efficiency. Table 8F.2.1 summarizes the labor hour differences and technology types. Based on RSMeans data, DOE assumed that the minimum labor hours required to perform maintenance tasks for a pool heaters is 1 hour, in addition to a 0.5 hours for the trip charge. For heat pump pool heaters, additional maintenance cost includes annual cleaning of the air filter and a preventative maintenance cost to check the evaporator and refrigeration system. DOE assumed that the maintenance costs are the same for all heat pump efficiency levels. For gas-fired condensing pool heaters the additional maintenance requirements include checking the condensate withdrawal system and condensate neutralizer if used.

Table 8F.2.1 Summary of Pool Heater Maintenance Costs

Repair Description	Trip Charge (in labor hours)	Labor Hours	Average National Cost (2021$)
Electric Pool Heaters			
Electric Resistance	0.5	1.0	$187
Heat Pump	0.5	1.125	$203
Gas-fired Pool Heaters			
Non-Condensing	0.5	1.0	$156
Condensing	0.5	1.125	$169

The total maintenance cost assumed by DOE is similar to the reported cost of performing annual maintenance from several websites.[5,6] DOE accounted for regional differences in labor costs, as is discussed in section 8F.4.

8F.3 REPAIR COST FOR POOL HEATERS

The repair cost is the cost to the consumer for replacing or repairing components in the furnace that have failed. DOE estimated repair costs at each considered efficiency level using a variety of sources, including *2022 RSMeans Facilities Repair and Maintenance Data*, manufacturer literature, information from expert consultants and several internet sources[5,7,8]. DOE accounted for regional differences in labor costs, as discussed in section 8F.4.

Table 8F.3.1 shows repair rate and cost assumptions that DOE used in its analysis. The failure year is assumed to be at two-thirds of the lifetime of the electric pool heater. The material cost for higher efficiency levels is adjusted based on the product cost ratio between baseline (electric resistance pool heater, non-condensing gas-fired pool heater) and the considered higher-efficiency heat pump pool heater and condensing gas-fired pool heater options.

Table 8F.3.1 Pool Heater Repair Costs

Repair Description	**Average Lifetime Component** (Years)	**Repair Rate**	**Material Cost** (2021$)*	**Total Labor Hours****	**Average National Cost** (2021$)
Electric Pool Heaters					
ERPH – Controls, Heating Element	5	25%	$200	1.5	$426
HPPH - Controls, Refrigerant Change , Condenser Fan	10	25%	$200	1.75	$457
HPPH - Compressor	15	12.5%	$1,000	8.0	$2,193
Gas-fired Pool Heaters					
GPH (EL 0) – Pilot Ignition Controls, Gas Valve	5	50%	$75	1.75	$269
GPH (non-condensing) – Electronic Ignition, Controls, Gas Valve	12	50%	$100	2.25	$350
GPH (Condensing) – Induced Draft	15	50%	$125	2.5	$405
GPH – Induced Draft	15	50%	$200	3.5	$596
GPH (Condensing) – Secondary Heat Exchanger	20	12.5%	$750	8.0	$1,704

*Does not include sales tax or markups by trade from RS Means.
** Includes 0.5 hour trip charge.

8F.4 REGIONAL MATERIAL AND LABOR COSTS

DOE used regional material and labor costs to more accurately estimate installation, maintenance, and repair costs by region. RSMeans provides average national labor costs for different trade groups. DOE used the residential repair and remodeling labor cost from RS Means crew type Q19 (1 Steamfitter, 1 Steamfitter, 1 Electrician) for all repair and maintenance labor cost calculations as shown in Table 8F.4.1. Bare costs are given in RS Means, while labor costs including overhead and profit (O&P) are the bare costs multiplied by the RS Means markups by trade.

Table 8F.4.1 RS Means 2021 National Average Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	**Incl. O&P***
2022 RS Means Labor Costs Data (Repair/Remodeling)				
Q19	1 Steamfitter, 1 Steamfitter Apprentice, 1 Electrician	3	$62.25	$95.87

* O&P includes markups from RS Means.

RSMeans also provides material and labor cost factors for 295 cities and towns in the U.S. To derive average labor cost values by state, DOE weighted the price factors by city or town population size using 2021 census data. DOE used the material and labor cost factors for cost associated with fire suppression, plumbing, and HVAC. See appendix 8D for more details.

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APPENDIX 8G. POOL HEATER LIFETIME DETERMINATION

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8G.1 INTRODUCTION

The product lifetime is the age at which a product is retired from service. Because product lifetime varies, U.S. Department of Energy (DOE) used a lifetime distribution to characterize the probability a product will be retired from service at a given age. DOE took into account published studies and manufacturer input, but because the basis for the estimates in the literature was uncertain, DOE developed a method using shipments and survey data to estimate the distribution of consumer pool heater lifetimes in the field.

8G.2 LIFETIME LITERATURE REVIEW

DOE performed a lifetime literature review. Table 8G.2.1 presents a range of product lifetimes and sources found by DOE.

DOE did not include the electric resistance pool heater and all pool heater references because it does not consider these lifetimes representative of the electric pool heaters considered in this analysis, which are large than 11 kW electric resistance pool heaters and heat pump pool heaters. Based on consultant input, an electric resistance pool heater in the same ambient conditions, pool water quality, and operating hours as a heat pump pool heater would have a similar lifetime as the heat pump pool heater or gas-fired pool heater.[1]

Table 8G.2.1 Pool Heaters: Product Lifetime Estimates and Sources

Typical Lifetime or Range (years)	Source
All Pool Heaters	
8-12	Kilmer (2010)[2]
8	LaPonsie (2012)[3]
4-7	Tiger Home Inspection[4]
8	InterNACHI[5]
4-10 (Southeastern Coast Area)	The Pool Guy Store (2010)[6]
Electric Resistance Pool Heater	
5-10	Miley[7]
4-6	Raypak, No. 4 at p. 6
Heat Pump Pool Heater	
10-20	Miley[7]
12-15	Low (2020)[8]
5-10	Pool for Thought (2013)[9]
10	AquaCal (2013)[10]
7-10	GulfStream[11]
nearly twice that of a fossil fuel heater	AquaComfort[12]
7-10	AHRI, No. 7 at p. 8
8-12	Raypak, No. 4 at p. 6
12	Poolheatpumps.com (2014)[13]
5-8 (Florida only)	InterNACHI[14]
10	Navigant Consulting (2015)[15]
10-25	Navigant Consulting (2015)[15]
10+	DOE (2012)[16]

8G.3 METHODOLOGY

DOE's lifetime methods are based on the approach described in Lutz *et al*. (2011)[17] and Franco *et al*. (2018).[18] The following flowchart summarizes DOE's approach for determining a lifetime distribution for consumer furnaces.

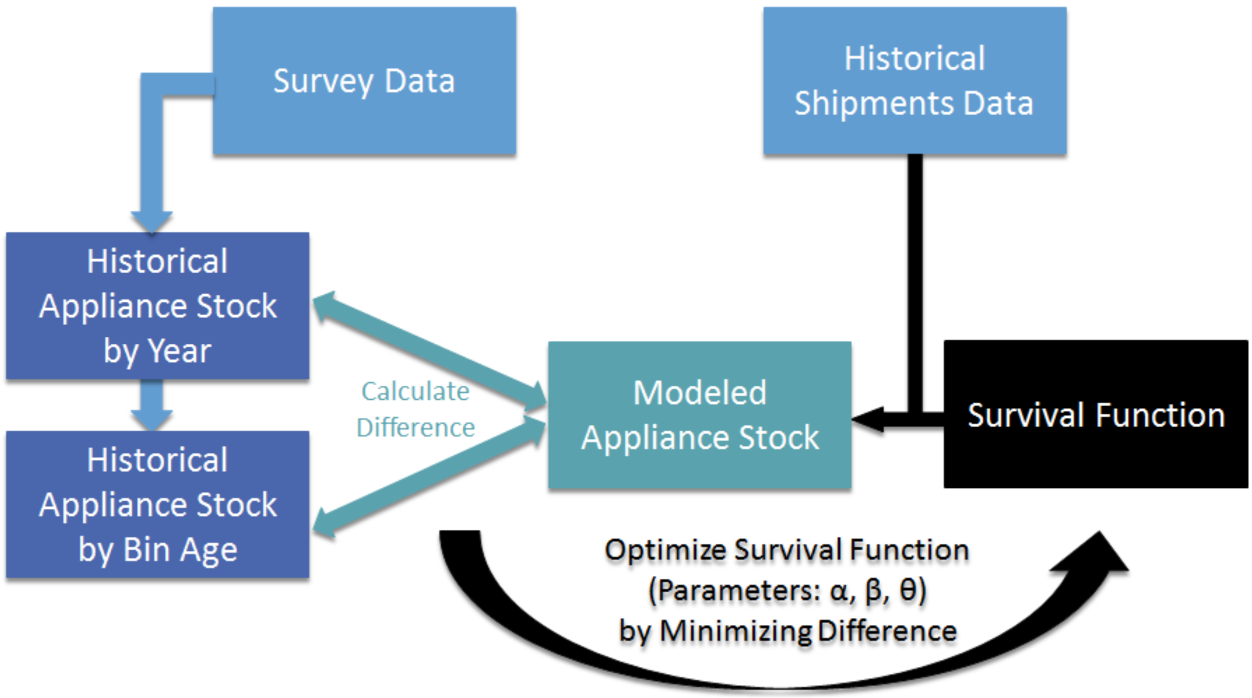

Figure 8G.3.1 Flowchart of Approach for Determining Lifetime Distribution for Consumer Furnaces

DOE assumed that the probability function for the annual survival of consumer pool heaters would take the form of a Weibull distribution. A Weibull distribution is a probability distribution commonly used to measure failure rates.[19] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a specific fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}}, for\ x > \theta, \text{ and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Eq. 8G.1

Where:

P(x) = probability that the appliance is still in use at age *x*,
x = age of appliance in years,
θ = delay parameter, which allows for a delay before any failures occur,
α = scale parameter, which would be the decay length in an exponential distribution, and
β = shape parameter, which determines the way in which the failure rate changes through time.

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age. DOE estimated a delay parameter of $\theta = 1$ year, based on the typical manufacturer warranty period for pool heaters. DOE derived a Weibull distribution for pool heater lifetime as part of the pool heater shipments model described in chapter 9, primarily using historical shipments data and pool heater stock data from Energy Information Administration (EIA)'s Residential Energy Consumption Survey ("RECS") 1987-2020[20] and 2022 Pkdata.[21] DOE assumed that the distribution of lifetimes would account for the impact of the pool water quality on the life of the product, the level of maintenance of a consumer pool heater, and the fraction of consumers winterizing the consumer pool heater.

Table 8G.3.1 summarize the results 1990–2020 RECS for total number of residential single-family households with a swimming pool or spa and number of swimming pools or spas that are being heated by energy source type.

Table 8G.3.1 Swimming Pools and Spas Stock by Heater Fuel Type Based on RECS 1990 to 2020 Data

	RECS Version Year (million Households)								
	1987	**1990**	**1993**	**1997**	**2001**	**2005**	**2009**	**2015**	**2020**
Number of Single-Family Households	60.5	64.4	66.8	73.7	73.7	79.7	78.6	80.9	84.5
Number of Swimming Pools	NA	4.89	4.45	5.47	6.55	8.30	7.94	8.21	8.11
Swimming Pools with Pool Heaters	0.97	1.06	0.82	1.10	1.21	1.94	2.06	2.52	2.89
Electric Pool Heaters	0.04	0.07	0.08	0.10	0.05	0.41	0.46	0.69	0.85
Gas Pool Heaters	0.79	0.84	0.54	0.81	1.00	1.52	1.34	1.42	1.62
Other Pool Heaters	0.15	0.15	0.20	0.19	0.16	0.01	0.26	0.42	0.42
Number of Spas	1.63	3.22	2.76	3.94	4.19	6.57	5.92	5.43	6.24
Electric Spa Heaters	0.60	1.66	1.88	2.60	3.07	5.19	4.23	3.56	4.41
Gas Spa Heaters	0.93	1.40	0.88	1.30	1.03	1.34	1.58	1.81	1.72
Other Spa Heaters	0.10	0.16	0.01	0.05	0.10	0.04	0.11	0.06	0.12

There are a significant number of single-family homes that have both a pool heater and a spa heater of the same fuel. As shown in Table 8G.3.2 and Table 8G.3.3, DOE disaggregated the sample into swimming pool only, swimming pool and spa, and spa only. In addition, a fraction of spas in RECS are not served from pool heaters that are within the scope of this rulemaking. To account for this DOE decreased the spa only weight by multiplying by 1.5 percent for electric pool heaters and half for gas-fired pool heater. DOE then calibrated the historical consumer pool heater shipments models by comparing the total stock of pool heaters reported from historical data sources, as shown in Table 8G.3.4.

Table 8G.3.2 Swimming Pools and Spas Stock for Electric Pool Heaters Based on RECS 1990 to 2020 Data

RECS Year	RECS Historical Stock Data (million)			
	Pool Only	Pool + Spa	Spa Only	Total PHs
1987	0.02	0.02	0.42	0.46
1990	0.07	0.00	1.53	1.60
1993	0.05	0.03	1.75	1.83
1997	0.06	0.04	2.45	2.55
2001	0.05	0.00	2.90	2.95
2005	0.21	0.19	4.99	5.40
2009	0.28	0.17	4.07	4.52
2015	0.46	0.22	3.36	4.05
2020	0.57	0.28	4.41	5.25

Table 8G.3.3 Swimming Pools and Spas Stock for Gas-fired Pool Heaters Based on RECS 1990 to 2020 Data

RECS Year	RECS Historical Stock Data (million)			
	Pool Only	Pool + Spa	Spa Only	Total PHs
1987	0.41	0.38	0.55	1.34
1990	0.49	0.35	1.05	1.89
1993	0.27	0.27	0.61	1.14
1997	0.48	0.33	0.97	1.78
2001	0.88	0.12	0.91	1.91
2005	1.09	0.43	0.91	2.43
2009	0.69	0.65	0.92	2.27
2015	0.75	0.66	1.14	2.56
2020	0.99	0.62	1.09	2.71

Table 8G.3.4 Historic Stock for Consumer Pool Heaters Based on RECS 1990 to 2020 Data Compared to Shipment Modeled Data

RECS Year	RECS Historical Stock Data (million)			
	Electric Pool Heater		Gas-fired Pool Heaters	
	Data	Modeled	Data	Modeled
1987	0.05	0.06	1.06	1.15
1990	0.09	0.06	1.37	1.25
1993	0.10	0.08	0.84	1.26
1997	0.14	0.13	1.29	1.31
2001	0.09	0.21	1.45	1.43
2005	0.48	0.31	1.97	1.64
2009	0.52	0.55	1.80	1.71
2015	0.74	0.71	1.99	1.79
2020	0.91	0.85	2.16	1.96

Table 8G.3.5 shows the Weibull distribution parameters for pool heaters and Figure 8G.3.1 displays the Weibull probability distribution. DOE assumed that the lifetimes of electric resistance pool heaters, heat pump pool heaters, and gas-fired pool heaters would be the same (average lifetime is 11.0 years). In addition, DOE assumed that the lifetime of all pool heaters would be the same across the different efficiency levels. The average lifetime value is within the range of the values found in the literature review.

Table 8G.3.5 Lifetime Parameters for Pool Heaters

Product Class	Weibull Parameters			Statistics	
	Alpha (scale)	Beta (shape)	Location (delay)	Mean	Median
All Pool Heaters	11.0	1.5	1.0	11.0	9.6

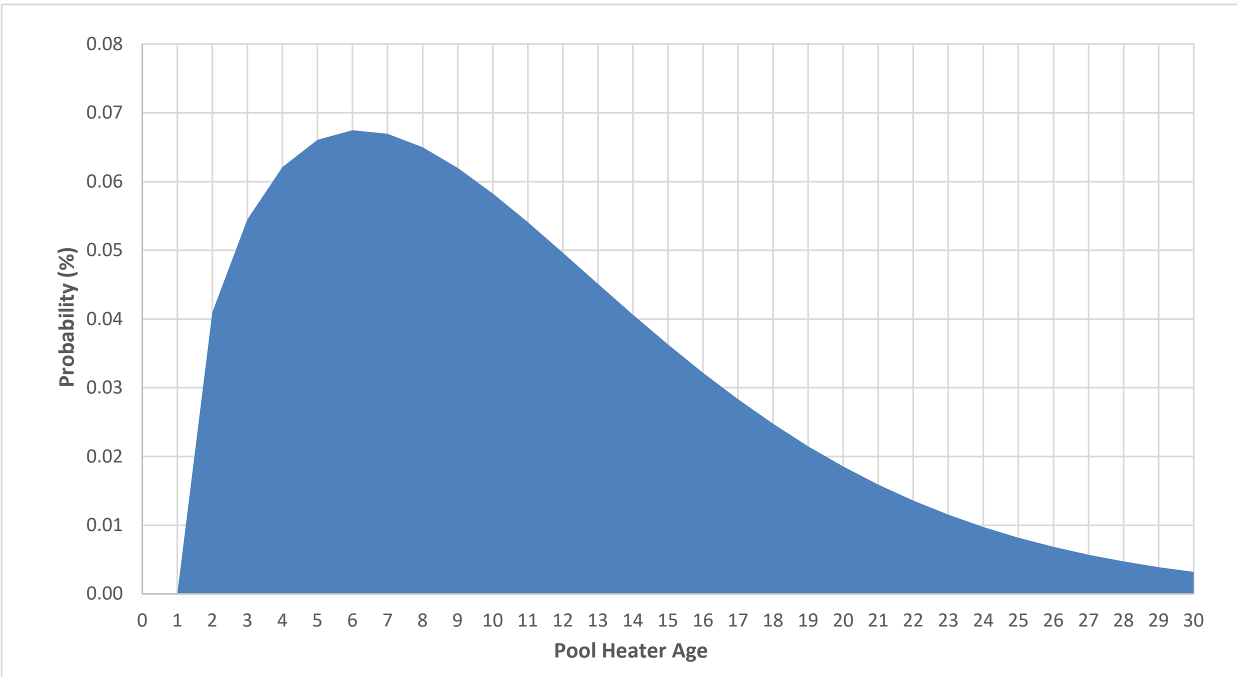

Figure 8G.3.2 Weibull Probability Distribution for Pool Heaters

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APPENDIX 8H. DISTRIBUTIONS USED FOR DISCOUNT RATES

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APPENDIX 8H. DISTRIBUTIONS USED FOR DISCOUNT RATES

8H.1 INTRODUCTION: DISTRIBUTIONS USED FOR RESIDENTIAL CONSUMER DISCOUNT RATES

The Department of Energy (DOE) derived consumer discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances* (*SCF*) in 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[1] To account for variation among households in rates for each of the types, DOE sampled a rate for each household in its building sample from a distribution of discount rates for each of six income groups. This appendix describes the distributions used.

8H.1.1 Distribution of Rates for Equity Classes

Figure 8H.1.1 through Figure 8H.1.6 show the distribution of real interest rates for different types of equity. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data (1992-2021). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1992-2021.[2] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1992-2021.[3] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1992-2021.[4,a] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1992-2016 and Bartel Associates for 2017-2021.[10,11,b] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1992–2021.[12] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1992–2021.[13] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[c] The 30-year average nominal interest rates are shown in Table 8H.1.1. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see Figure 8H.1.7). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in chapter 8 (the impact of this is not shown in Figure 8H.1.1 through Figure 8H.1.6, which are only adjusted for inflation).

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[a] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[5,6] From July 2007 to October 2009 the index was known as Wachovia COSI[7] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[8,9]

[b] This index was discontinued in 2016. To calculate the 2017 and after values, DOE used data collected by Bartel Associates.

[c] SCF reports what type of mutual funds the household has (*e.g.,* stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8H.1.1 30-Year Average Nominal Interest Rates for Household Equity Type

Type of Equity	30 Year Average Nominal Rate (%)
Savings accounts	2.49
Money market accounts	2.65
Certificate of deposit	2.92
Treasury Bills (T-bills)	4.62
State/Local bonds	4.57
AAA Corporate Bonds	5.48
Stocks (S&P 500)	11.98
Mutual funds	9.52

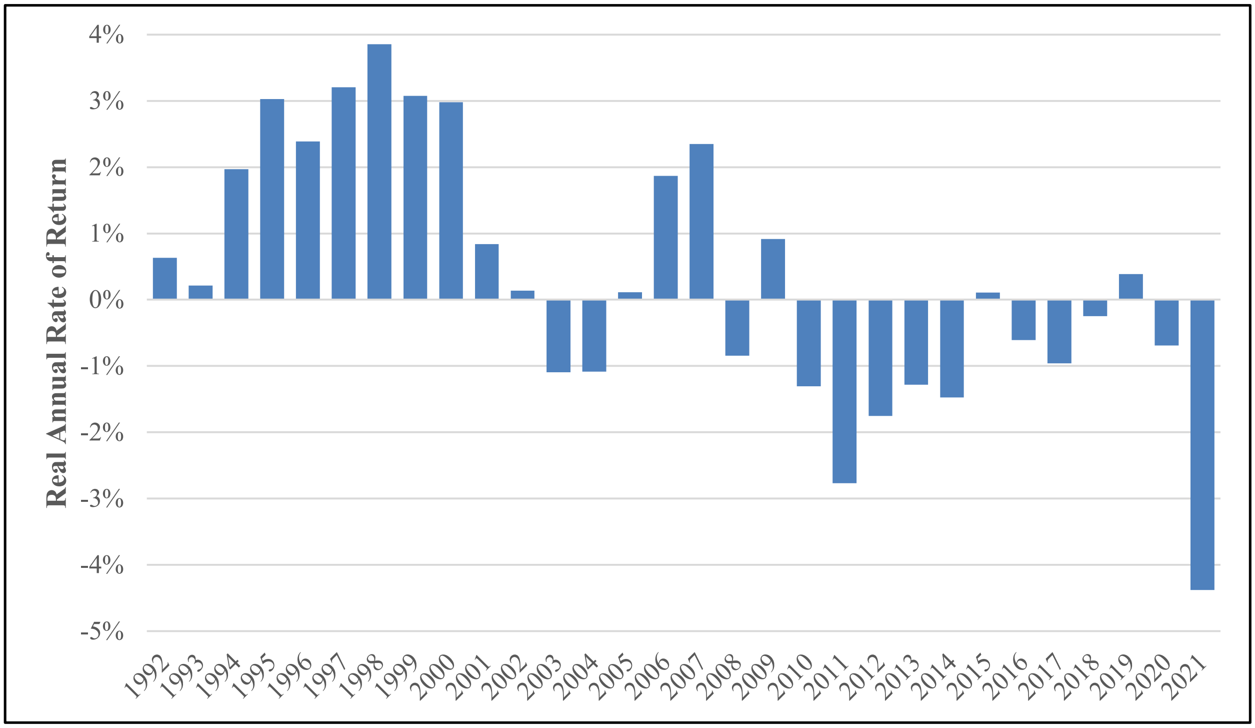

Figure 8H.1.1 Distribution of Annual Rate of Money Market Accounts

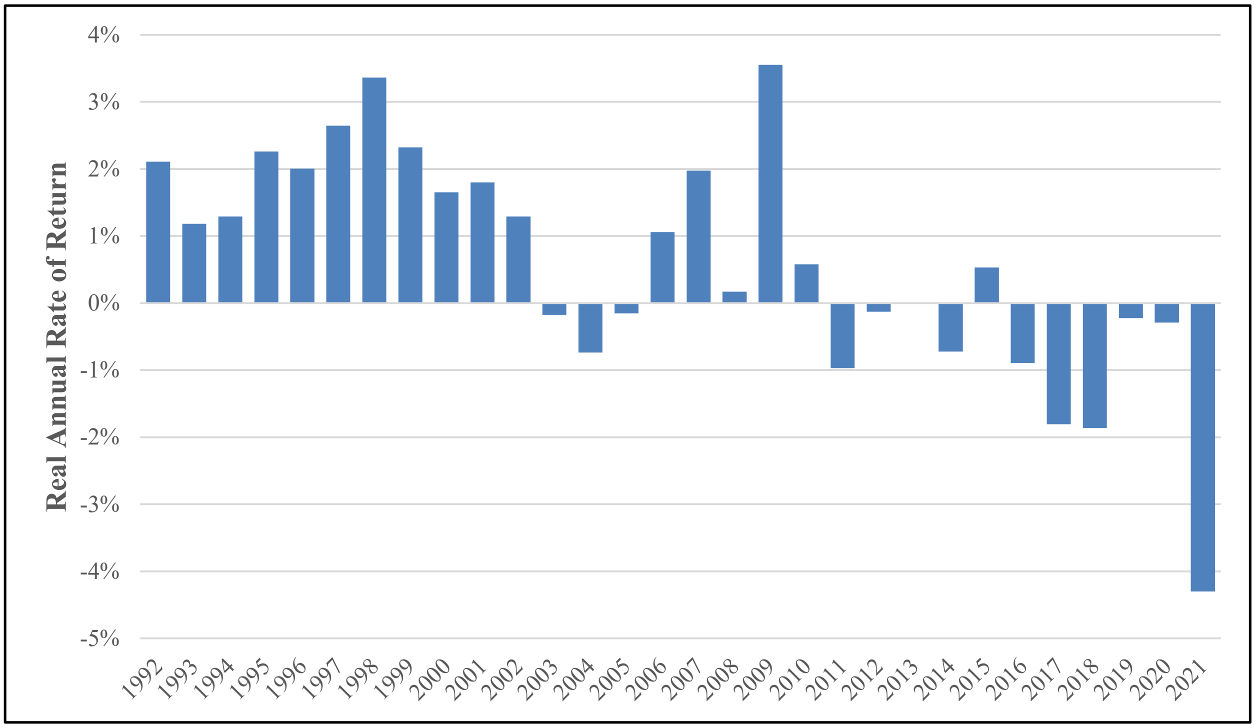

Figure 8H.1.2 Distribution of Annual Rate of Return on CDs

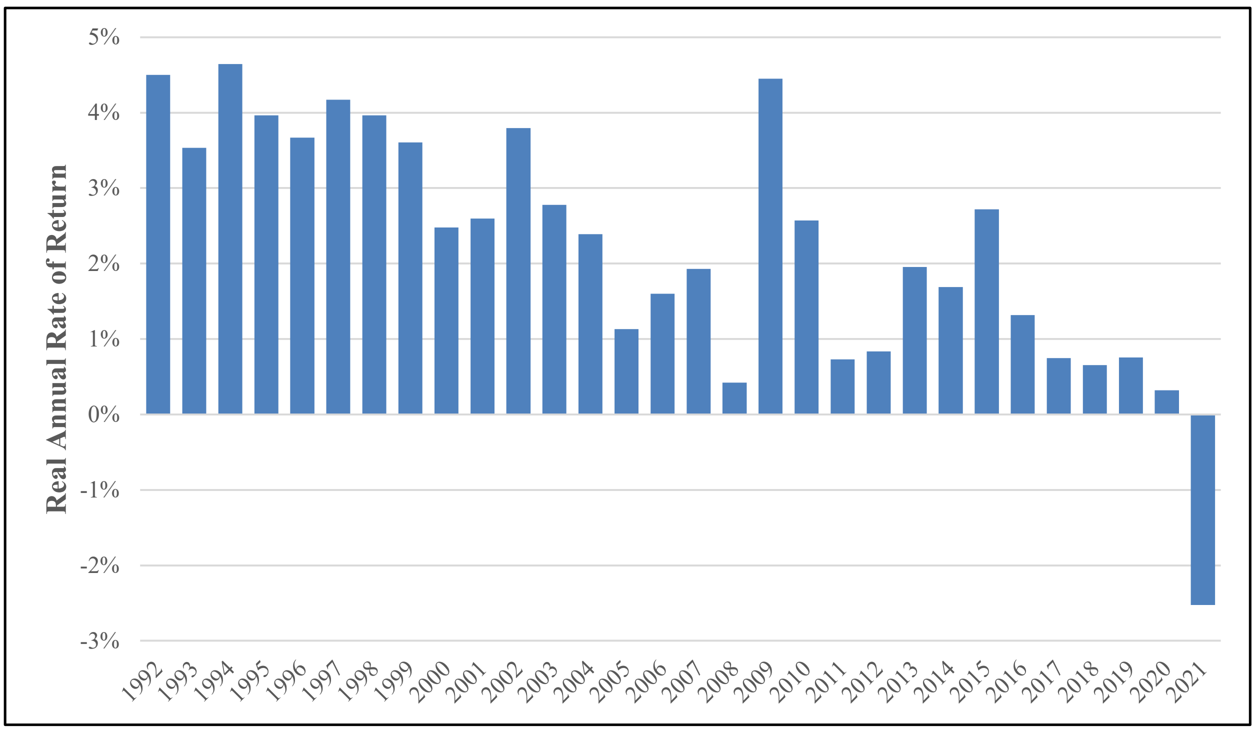

Figure 8H.1.3 Distribution of Annual Rate of Return on Savings Bonds (30 Year Treasury Bills)

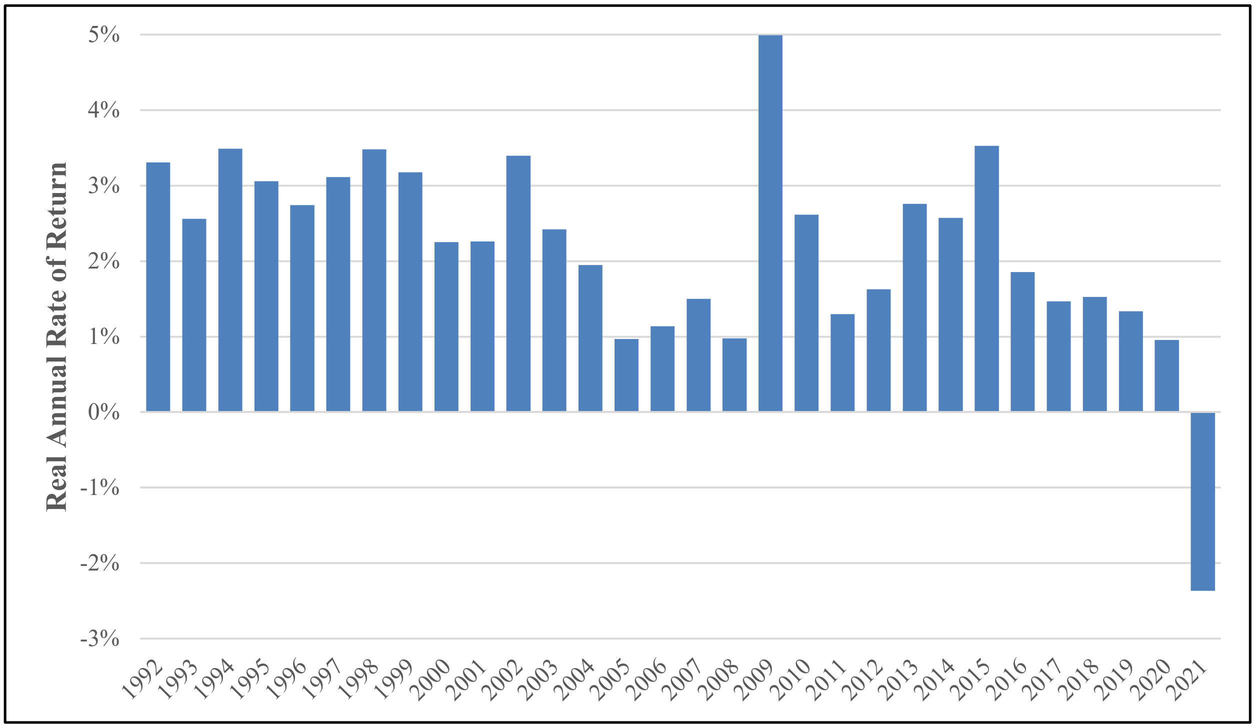

Figure 8H.1.4 Distribution of Annual Rate of State and Local Bonds

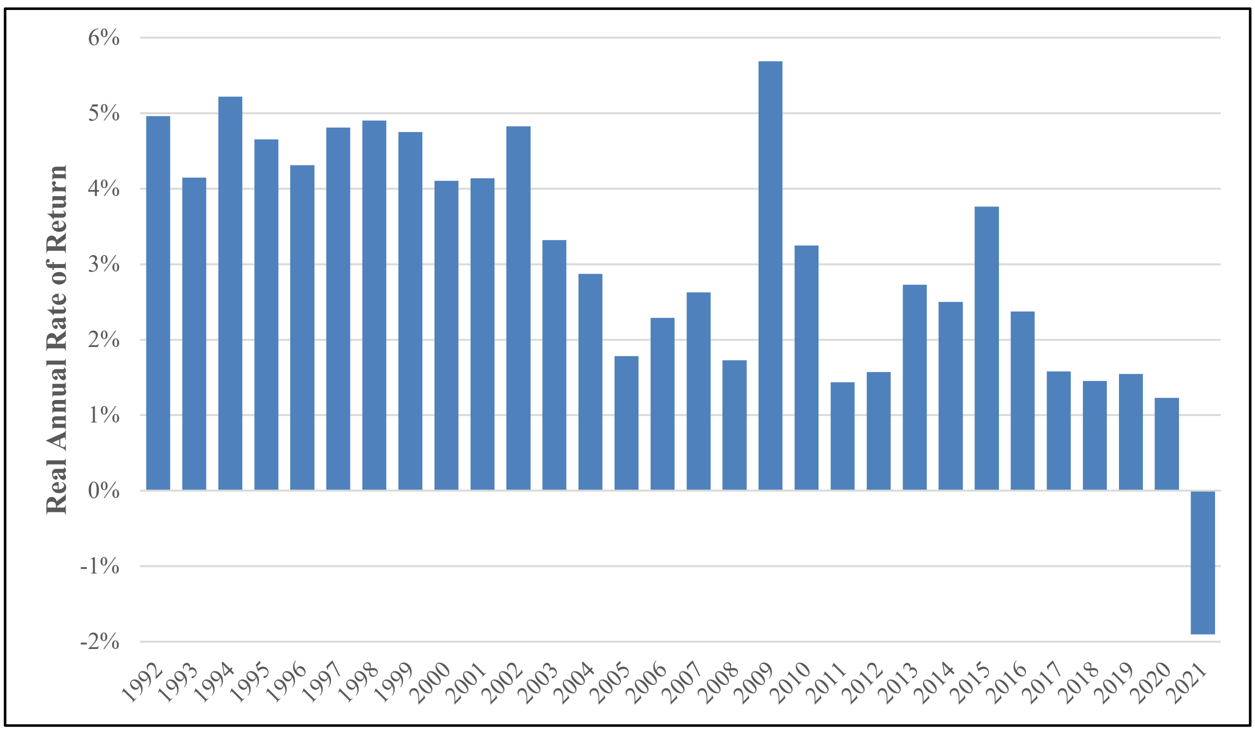

Figure 8H.1.5 Distribution of Annual Rate of Return on Corporate AAA Bonds

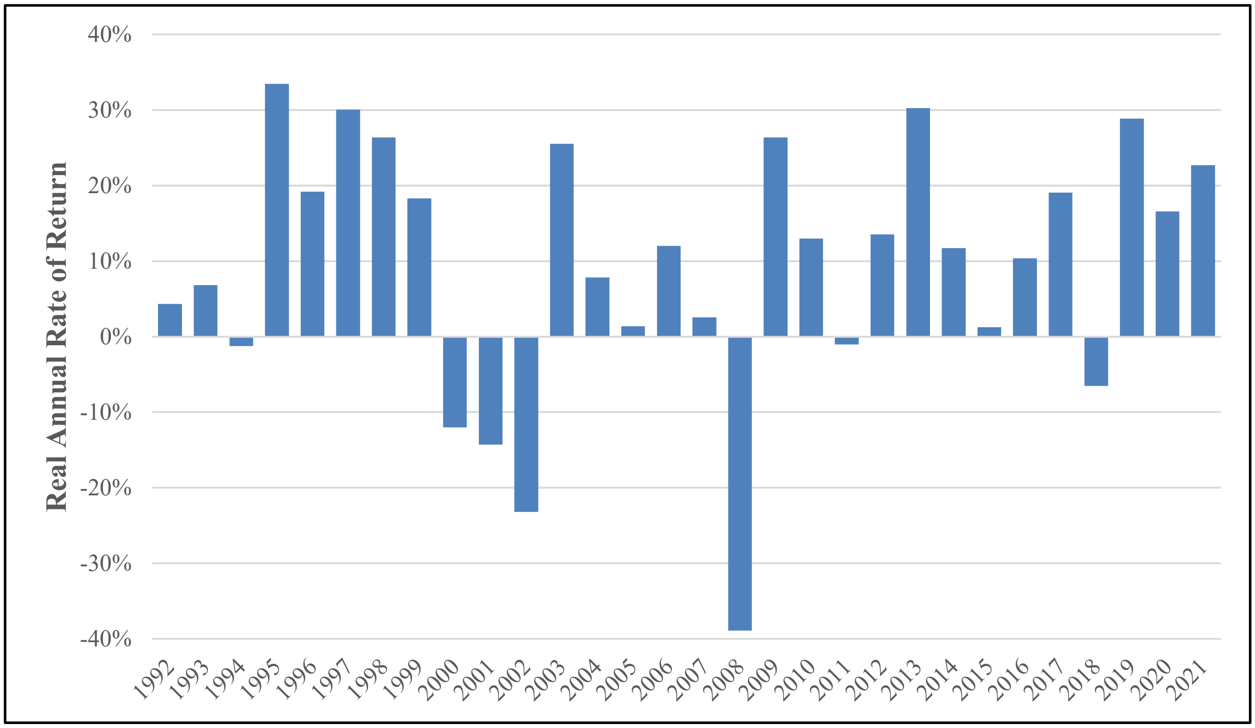

Figure 8H.1.6 Distribution of Annual Rate of Return on S&P 500

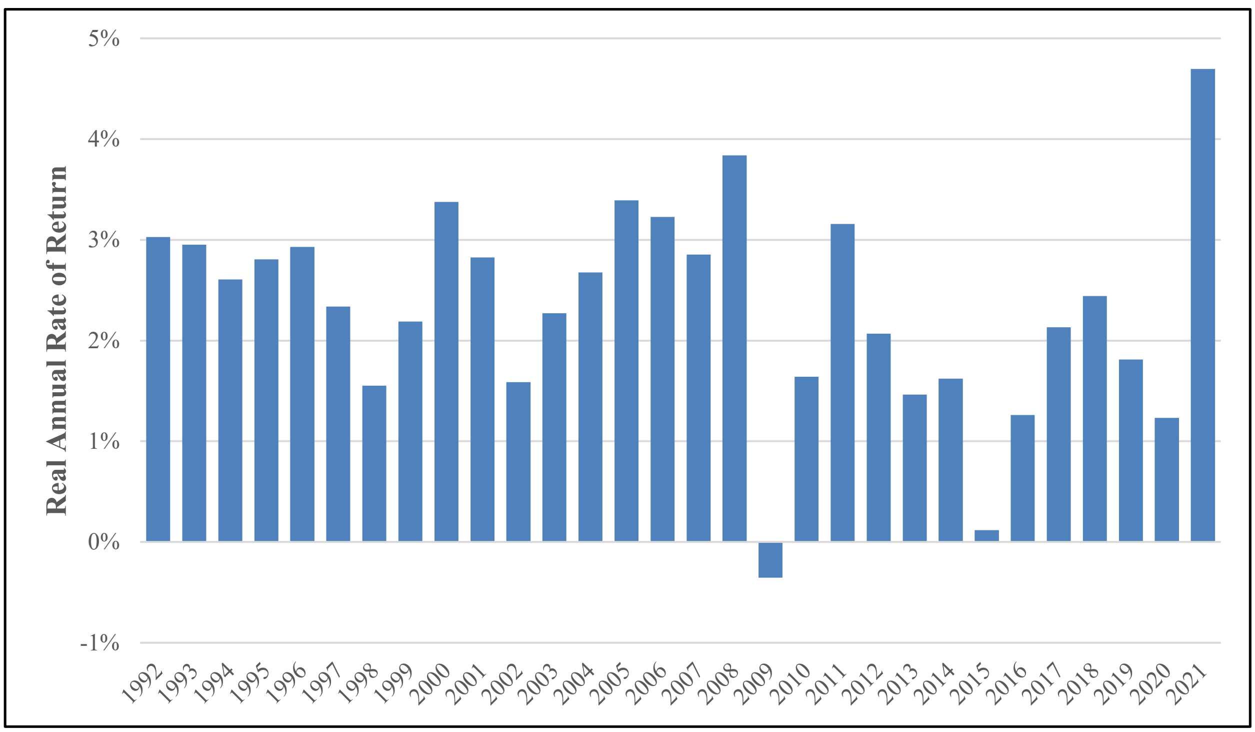

Figure 8H.1.7 Annual Consumer Price Index (CPI) Rate

8H.2 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Real effective discount rates were calculated for each household of the SCF using the method described in chapter 8. Interest rates for asset types were as described in 8H.1.1. The data source for the interest rates for mortgages, home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage interest rate and the nominal home equity loan interest rate for each relevant household in the *SCF* for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero. Figure 8H.2.1 provides a graphical representation of the real effective discount rate distributions by income group, while Table 8H.2.1 provides the full distributions as used in the LCC analysis.

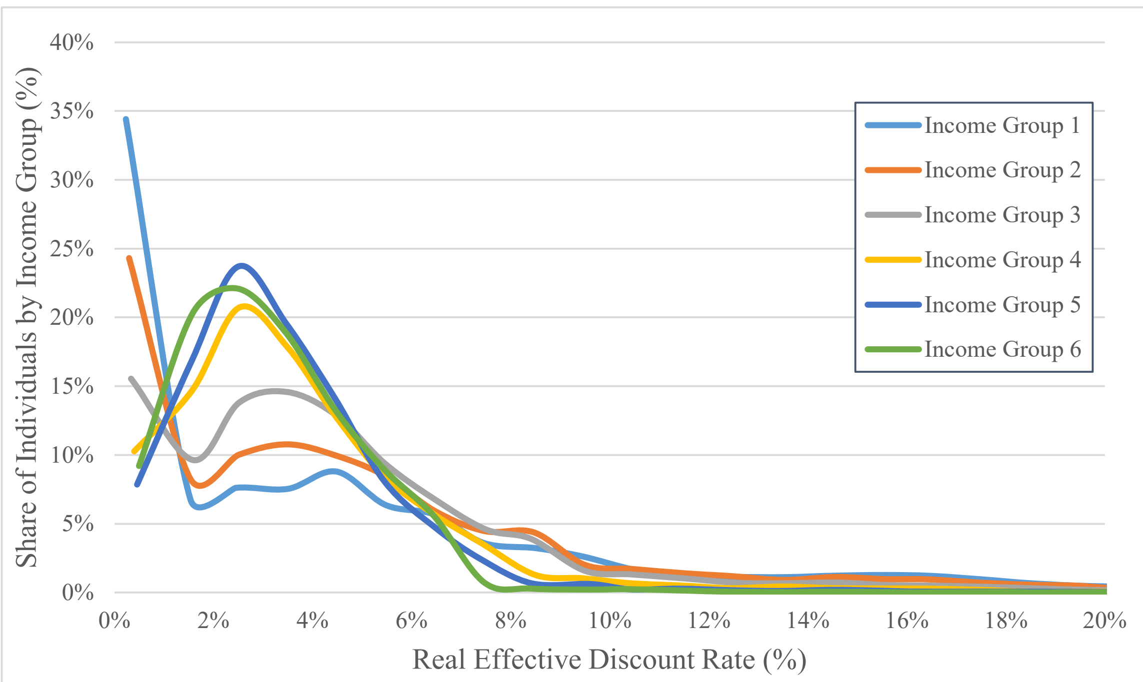

Figure 8H.2.1 Distribution of Real Discount Rates by Income Group

Table 8H.2.1 Distribution of Real Discount Rates by Income Group

DR Bin (%)	Income Group 1 (0-19.9 percentile)		Income Group 2 (20-39.9 percentile)		Income Group 3 (40-59.9 percentile)		Income Group 4 (60-79.9 percentile)		Income Group 5 (80-89.9 percentile)		Income Group 6 (90-100 percentile)	
	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %
0-1	0.23	34.42	0.29	24.30	0.34	15.54	0.40	10.28	0.46	7.85	0.50	9.20
1-2	1.54	6.76	1.53	8.26	1.58	9.63	1.57	14.70	1.57	16.87	1.58	20.30
2-3	2.46	7.62	2.51	10.01	2.52	13.80	2.52	20.73	2.51	23.71	2.50	22.09
3-4	3.51	7.55	3.49	10.77	3.49	14.57	3.49	17.87	3.47	19.54	3.47	18.86
4-5	4.48	8.80	4.47	9.95	4.48	12.88	4.47	12.82	4.45	14.15	4.48	13.18
5-6	5.47	6.38	5.46	8.47	5.46	9.39	5.46	8.41	5.46	8.07	5.46	8.92
6-7	6.47	5.67	6.47	5.93	6.46	6.80	6.45	5.70	6.50	4.66	6.45	5.57
7-8	7.46	3.61	7.47	4.46	7.51	4.59	7.44	3.54	7.40	2.42	7.47	0.73
8-9	8.52	3.23	8.47	4.36	8.41	3.91	8.49	1.30	8.43	0.66	8.41	0.29
9-10	9.46	2.63	9.49	2.01	9.49	1.60	9.46	1.05	9.62	0.62	9.63	0.22
10-11	10.50	1.66	10.46	1.70	10.44	1.33	10.43	0.69	10.44	0.22	10.36	0.25
11-12	11.48	1.16	11.53	1.39	11.52	1.03	11.54	0.51	11.41	0.28	11.54	0.14
12-13	12.52	1.14	12.47	1.19	12.54	0.72	12.45	0.33	12.48	0.16	12.39	0.06
13-14	13.54	1.13	13.52	0.91	13.50	0.69	13.48	0.45	13.43	0.11	13.52	0.02
14-15	14.52	1.23	14.56	1.13	14.60	0.74	14.50	0.34	14.53	0.19	14.45	0.06
15-16	15.55	1.29	15.55	0.97	15.53	0.56	15.48	0.31	15.43	0.13	15.64	0.02
16-17	16.49	1.22	16.40	0.96	16.46	0.51	16.43	0.30	16.17	0.06	16.40	0.01
17-18	17.58	0.95	17.51	0.71	17.51	0.43	17.47	0.21	17.53	0.06	17.93	0.03
18-19	18.42	0.70	18.47	0.56	18.41	0.34	18.37	0.10	18.47	0.06	18.50	0.01
19-20	19.45	0.51	19.40	0.50	19.45	0.22	19.61	0.09	19.40	0.05	19.17	0.01
20-21	20.56	0.44	20.42	0.26	20.38	0.18	20.46	0.09	20.47	0.04	20.13	0.02
21-22	21.43	0.54	21.43	0.34	21.34	0.16	21.48	0.07	21.38	0.06	0.00	0.00
22-23	22.51	0.39	22.48	0.23	22.58	0.08	22.72	0.03	0.00	0.00	0.00	0.00
23-24	23.41	0.17	23.52	0.13	23.40	0.10	23.44	0.02	0.00	0.00	23.89	0.03
24-25	24.61	0.18	24.47	0.10	24.56	0.04	24.08	0.01	0.00	0.00	0.00	0.00
25-26	25.35	0.16	25.40	0.10	25.47	0.06	25.33	0.03	25.79	0.00	0.00	0.00
26-27	26.52	0.13	26.47	0.03	26.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00
27-28	27.49	0.07	27.41	0.02	27.41	0.03	27.27	0.03	27.14	0.00	0.00	0.00
28-29	28.14	0.09	28.29	0.05	28.38	0.01	0.00	0.00	0.00	0.00	0.00	0.00
29-30	29.87	0.01	29.37	0.01	29.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>30	68.17	0.14	125.34	0.19	135.28	0.02	53.82	0.00	0.00	0.00	0.00	0.00
Total	4.71	100.00	4.95	100.00	4.51	100.00	3.80	100.00	3.44	100.00	3.19	100.00

8H.3 DISTRIBUTIONS USED FOR COMMERCIAL/INDUSTRIAL DISCOUNT RATES

Table 8H.3.1 Education Sector Discount Rate Distribution

Bin	Bin Range	Rates	Weight (% of companies)	# of Companies
1	<0%			
2	≥0 to <1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	5.33%	17.6%	141
8	6-7%	6.62%	40.0%	320
9	7-8%	7.44%	12.6%	101
10	8-9%	8.40%	20.7%	166
11	9-10%	9.38%	9.1%	73
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**7.12%**		

Table 8H.3.2 Food Sales Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.79%	2.9%	25
6	4-5%	4.63%	47.2%	409
7	5-6%	5.60%	23.2%	201
8	6-7%	6.29%	13.3%	115
9	7-8%	7.61%	3.8%	33
10	8-9%	8.76%	5.8%	50
11	9-10%	9.28%	2.1%	18
12	10-11%	10.32%	1.7%	15
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**5.60%**		

Table 8H.3.3 Food Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.88%	9.8%	180
7	5-6%	5.54%	31.1%	572
8	6-7%	6.56%	36.8%	677
9	7-8%	7.24%	18.0%	332
10	8-9%			
11	9-10%	9.79%	4.3%	79
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.34%**		

Table 8H.3.4 Health Care Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	5.59%	31.6%	1710
8	6-7%	6.47%	26.4%	1428
9	7-8%	7.40%	22.6%	1222
10	8-9%	8.42%	19.5%	1056
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.78%**		

Table 8H.3.5 Lodging Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.78%	24.0%	389
7	5-6%	5.49%	16.9%	274
8	6-7%	6.47%	23.8%	385
9	7-8%	7.29%	25.7%	416
10	8-9%	8.36%	5.5%	89
11	9-10%	9.98%	4.1%	66
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.35%**		

Table 8H.3.6 Mercantile Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.75%	0.9%	50
7	5-6%	5.58%	16.8%	926
8	6-7%	6.50%	36.0%	1984
9	7-8%	7.43%	34.2%	1884
10	8-9%	8.18%	9.7%	536
11	9-10%	9.16%	2.1%	115
12	10-11%	10.69%	0.3%	15
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.88%**		

Table 8H.3.7 Office Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.78%	6.4%	2902
6	4-5%	4.58%	17.3%	7771
7	5-6%	5.50%	21.7%	9772
8	6-7%	6.44%	14.7%	6615
9	7-8%	7.49%	9.2%	4159
10	8-9%	8.58%	15.2%	6839
11	9-10%	9.35%	8.2%	3710
12	10-11%	10.44%	2.8%	1282
13	11-12%	11.36%	1.7%	776
14	12-13%	12.82%	1.9%	838
15	≥13%	14.36%	0.8%	342
Weighted Average		**6.78%**		

Table 8H.3.8 Public Assembly Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.99%	2.0%	73
7	5-6%	5.71%	7.7%	285
8	6-7%	6.51%	40.2%	1487
9	7-8%	7.44%	27.9%	1031
10	8-9%	8.51%	14.2%	525
11	9-10%	9.11%	8.0%	297
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**7.17%**		

Table 8H.3.9 Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.85%	5.2%	818
6	4-5%	4.44%	13.7%	2133
7	5-6%	5.53%	29.2%	4559
8	6-7%	6.38%	25.3%	3941
9	7-8%	7.55%	12.3%	1926
10	8-9%	8.57%	9.9%	1549
11	9-10%	9.15%	4.4%	680
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.22%**		

Table 8H.3.10 All Commercial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.79%	4.7%	3745
6	4-5%	4.57%	13.8%	11084
7	5-6%	5.52%	23.0%	18497
8	6-7%	6.45%	21.1%	16953
9	7-8%	7.46%	13.8%	11125
10	8-9%	8.53%	13.4%	10810
11	9-10%	9.32%	6.3%	5038
12	10-11%	10.44%	1.6%	1312
13	11-12%	11.36%	1.0%	776
14	12-13%	12.82%	1.0%	838
15	≥13%	14.36%	0.4%	342
Weighted Average		**6.67%**		

Table 8H.3.11 Industrial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%	1.61%	0.0%	13
4	2-3%	2.63%	0.1%	59
5	3-4%	3.67%	1.6%	1257
6	4-5%	4.62%	6.8%	5350
7	5-6%	5.55%	19.4%	15185
8	6-7%	6.47%	21.0%	16461
9	7-8%	7.51%	16.1%	12632
10	8-9%	8.49%	23.1%	18090
11	9-10%	9.47%	8.1%	6301
12	10-11%	10.54%	2.8%	2213
13	11-12%	11.59%	0.4%	282
14	12-13%	12.52%	0.4%	285
15	≥13%	13.06%	0.2%	121
Weighted Average		**7.16%**		

Table 8H.3.12 Agriculture Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.68%	76.7%	207
9	7-8%	7.38%	11.5%	31
10	8-9%	8.15%	11.9%	32
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.94%**		

Table 8H.3.13 R.E.I.T./Property Management Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.90%	10.8%	466
7	5-6%	5.48%	19.3%	833
8	6-7%	6.34%	44.4%	1913
9	7-8%	7.47%	14.1%	609
10	8-9%	8.46%	9.8%	422
11	9-10%	9.14%	1.6%	70
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.43%**		

Table 8H.3.14 Investor-Owned Utility Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%	1.61%	0.6%	13
4	2-3%	2.50%	0.8%	16
5	3-4%	3.67%	49.9%	1064
6	4-5%	4.32%	39.0%	832
7	5-6%	5.42%	4.3%	91
8	6-7%	6.47%	3.9%	83
9	7-8%	7.30%	1.5%	33
10	8-9%			
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**4.14%**		

Table 8H.3.15 State/Local Government Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of years)	# of Years
1	<0%			
2	0-1%			
3	1-2%	1.6%	15.6%	5
4	2-3%	2.5%	25.0%	8
5	3-4%	3.6%	43.8%	14
6	4-5%	4.1%	6.3%	2
7	5-6%	5.3%	9.4%	3
8	6-7%			
9	7-8%			
10	8-9%			
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	>13%			
Weighted Average		**3.21%**		

Table 8H.3.16 Federal Government Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of months)	# of Months
1	<0%	-0.5%	7.6%	29
2	0-1%	0.5%	23.2%	89
3	1-2%	1.6%	16.1%	62
4	2-3%	2.5%	18.8%	72
5	3-4%	3.5%	18.8%	72
6	4-5%	4.3%	12.5%	48
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%			
11	9-10%			
12	10-11%			
13	11-12%			
14	12-13%			
15	>13%			
Weighted Average		**2.17%**		

8H.4 ASSIGNMENT OF DETAILED DATA TO AGGREGATE SECTORS FOR DISCOUNT RATE ANALYSIS

Table 8H.4.1 Detailed Industries Assigned to Each Aggregate CBECS PBA Sector

Aggregate Sector for CBECS Mapping	Detailed Sector Names as Provided in Damodaran Online Data Sets (1998-2018)
Education	Education; Educational Services
Food Sales	Food Wholesalers; Grocery; Retail (Grocery and Food); Retail/Wholesale Food
Food Service	Restaurant; Restaurant/Dining
Health Care	Healthcare Facilities; Healthcare Information; Healthcare Services; Healthcare Support Services; Healthcare Information and Technology; Hospitals/Healthcare Facilities; Medical Services
Lodging	Hotel/Gaming
Mercantile	Drugstore; Retail (Automotive); Retail (Building Supply); Retail (Distributors); Retail (General); Retail (Hardlines); Retail (Softlines); Retail (Special Lines); Retail Automotive; Retail Building Supply; Retail Store
Office	Advertising; Bank; Bank (Canadian); Bank (Midwest); Bank (Money Center); Banks (Regional); Broadcasting; Brokerage & Investment Banking; Business & Consumer Services; Cable TV; Computer Services; Computer Software; Computer Software/Svcs; Diversified; Diversified Co.; E-Commerce; Human Resources; Insurance (General); Insurance (Life); Insurance (Prop/Cas.); Internet; Investment Co.; Investment Co.(Foreign); Investment Companies; Investments & Asset Management; Property Management; Public/Private Equity; R.E.I.T.; Real Estate (Development); Real Estate (General/Diversified); Real Estate (Operations & Services); Reinsurance; Retail (Internet); Retail (Online); Securities Brokerage; Software (Entertainment); Software (Internet); Software (System & Application); Telecom. Utility; Thrift
Public Assembly	Entertainment; Recreation
Service	Financial Svcs.; Financial Svcs. (Div.); Financial Svcs. (Non-bank & Insurance); Foreign Telecom.; Funeral Services; Industrial Services; Information Services; Internet software and services; IT Services; Office Equip/Supplies; Office Equipment & Services; Oilfield Svcs/Equip.; Pharmacy Services; Telecom. Services
All Commercial	All detailed sectors included in: Education, Food Sales, Food Service, Health Care, Mercantile, Office, Public Assembly, Service
Industrial	Aerospace/Defense; Air Transport; Aluminum; Apparel; Auto & Truck; Auto Parts; Auto Parts (OEM); Auto Parts (Replacement); Automotive; Beverage; Beverage (Alcoholic); Beverage (Soft); Biotechnology; Building Materials; Cement & Aggregates; Chemical (Basic); Chemical (Diversified); Chemical (Specialty); Coal; Coal & Related Energy; Computers/Peripherals; Construction; Construction Supplies; Copper; Drug; Drugs (Biotechnology); Drugs (Pharmaceutical); Electric Util. (Central); Electric Utility (East); Electric Utility (West); Electrical Equipment; Electronics; Electronics (Consumer & Office); Electronics (General); Engineering; Engineering & Const; Engineering/Construction; Entertainment Tech; Environmental; Environmental & Waste Services; Food Processing; Foreign Electronics; Furn/Home Furnishings; Gold/Silver Mining; Green & Renewable Energy; Healthcare Equipment; Healthcare Products; Heavy Construction; Heavy Truck & Equip; Heavy Truck/Equip Makers; Home Appliance; Homebuilding; Household Products; Machinery; Manuf. Housing/RV; Maritime; Med Supp Invasive; Med Supp Non-Invasive; Medical Supplies; Metal Fabricating; Metals & Mining; Metals & Mining (Div.); Natural Gas (Div.); Natural Gas Utility; Newspaper; Oil/Gas (Integrated); Oil/Gas (Production and Exploration); Oil/Gas Distribution; Packaging & Container; Paper/Forest Products; Petroleum (Integrated); Petroleum (Producing); Pharma & Drugs; Pipeline MLPs; Power; Precious Metals; Precision Instrument; Publishing; Publishing & Newspapers; Railroad; Rubber& Tires; Semiconductor; Semiconductor Equip; Shipbuilding & Marine; Shoe; Steel; Steel (General); Steel (Integrated); Telecom (Wireless); Telecom. Equipment; Textile; Tire & Rubber; Tobacco; Toiletries/Cosmetics; Transportation; Transportation (Railroads); Trucking; Utility (Foreign); Utility (General); Utility (Water); Water Utility; Wireless Networking
Agriculture	Farming/Agriculture
Utilities	Natural Gas Utility; Utility (Foreign); Utility (General); Utility (Water); Water Utility
R.E.I.T. / Property	Property Management; R.E.I.T.; Real Estate (Development); Real Estate (General/Diversified); Real Estate (Operations & Services)

8H.5 SMALL BUSINESS DISCOUNT RATE DISTRIBUTIONS BY SECTOR

Table 8H.5.1 Education Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	≥0 to <1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.85%	8.7%	70
11	9-10%	9.24%	24.0%	192
12	10-11%	10.49%	44.6%	357
13	11-12%	11.55%	18.5%	148
14	12-13%	12.20%	4.2%	34
15	≥13%			
Weighted Average		**10.32%**		

Table 8H.5.2 Food Sales Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.49%	12.0%	104
9	7-8%	7.43%	47.0%	407
10	8-9%	8.38%	26.0%	225
11	9-10%	9.33%	3.6%	31
12	10-11%	10.67%	3.9%	34
13	11-12%	11.76%	3.7%	32
14	12-13%	12.05%	2.1%	18
15	≥13%	14.25%	1.7%	15
Weighted Average		**8.13%**		

Table 8H.5.3 Food Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%	7.98%	5.2%	95
10	8-9%	8.50%	36.9%	679
11	9-10%	9.44%	41.1%	757
12	10-11%	10.09%	8.1%	149
13	11-12%	11.38%	4.4%	81
14	12-13%	12.15%	4.3%	79
15	≥13%			
Weighted Average		**9.27%**		

Table 8H.5.4 Health Care Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%	7.60%	4.0%	218
10	8-9%	8.56%	36.4%	1973
11	9-10%	9.44%	24.2%	1310
12	10-11%	10.48%	21.1%	1144
13	11-12%	11.63%	12.2%	659
14	12-13%	12.74%	2.1%	112
15	≥13%			
Weighted Average		**9.60%**		

Table 8H.5.5 Lodging Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.57%	17.9%	290
9	7-8%	7.53%	17.3%	280
10	8-9%	8.45%	17.5%	284
11	9-10%	9.40%	33.4%	540
12	10-11%	10.88%	5.5%	89
13	11-12%	11.64%	8.4%	136
14	12-13%			
15	≥13%			
Weighted Average		**8.67%**		

Table 8H.5.6 Mercantile Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.91%	0.3%	15
9	7-8%	7.74%	0.8%	43
10	8-9%	8.74%	14.0%	769
11	9-10%	9.56%	53.3%	2935
12	10-11%	10.30%	23.8%	1312
13	11-12%	11.34%	7.5%	413
14	12-13%	12.23%	0.1%	8
15	≥13%	13.37%	0.3%	15
Weighted Average		**9.75%**		

Table 8H.5.7 Office Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.23%	1.0%	433
7	5-6%	5.64%	3.9%	1771
8	6-7%	6.36%	12.1%	5429
9	7-8%	7.48%	17.2%	7720
10	8-9%	8.54%	15.7%	7064
11	9-10%	9.49%	11.4%	5140
12	10-11%	10.41%	10.3%	4635
13	11-12%	11.58%	8.8%	3951
14	12-13%	12.45%	10.3%	4639
15	≥13%	14.83%	9.4%	4224
Weighted Average		**9.50%**		

Table 8H.5.8 Public Assembly Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.56%	22.9%	847
11	9-10%	9.56%	37.9%	1403
12	10-11%	10.51%	19.2%	709
13	11-12%	11.66%	15.7%	579
14	12-13%	12.36%	4.3%	160
15	≥13%			
Weighted Average		**9.96%**		

Table 8H.5.9 Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.33%	8.6%	1341
7	5-6%	5.67%	4.9%	770
8	6-7%	6.37%	14.2%	2210
9	7-8%	7.14%	5.2%	808
10	8-9%	8.54%	23.1%	3601
11	9-10%	9.45%	23.3%	3629
12	10-11%	10.48%	10.5%	1643
13	11-12%	11.54%	5.9%	920
14	12-13%	12.37%	3.5%	554
15	≥13%	13.11%	0.8%	130
Weighted Average		**8.43%**		

Table 8H.5.10 All Commercial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.31%	2.2%	1774
7	5-6%	5.65%	3.2%	2541
8	6-7%	6.38%	10.0%	8081
9	7-8%	7.46%	12.0%	9628
10	8-9%	8.55%	19.3%	15579
11	9-10%	9.49%	19.8%	15937
12	10-11%	10.42%	12.5%	10073
13	11-12%	11.57%	8.6%	6919
14	12-13%	12.44%	7.0%	5604
15	≥13%	14.77%	5.4%	4384
Weighted Average		**9.31%**		

Table 8H.5.11 Industrial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%	3.48%	0.0%	29
5	3-4%	4.66%	0.4%	278
6	4-5%	5.58%	1.8%	1421
7	5-6%	6.53%	3.3%	2571
8	6-7%	7.55%	9.3%	7310
9	7-8%	8.49%	14.7%	11473
10	8-9%	9.51%	18.6%	14586
11	9-10%	10.51%	20.1%	15729
12	10-11%	11.42%	17.7%	13839
13	11-12%	12.50%	8.7%	6815
14	12-13%	14.20%	5.4%	4198
15	≥13%	3.48%	0.0%	29
Weighted Average		**10.04%**		

Table 8H.5.12 Agriculture Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.65%	39.6%	107
11	9-10%	9.33%	35.9%	97
12	10-11%	10.30%	24.4%	66
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**9.30%**		

Table 8H.5.13 R.E.I.T./Property Management Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	5.75%	0.4%	16
8	6-7%	6.48%	2.6%	114
9	7-8%	7.67%	22.0%	951
10	8-9%	8.40%	36.4%	1570
11	9-10%	9.52%	24.3%	1046
12	10-11%	10.41%	10.3%	443
13	11-12%	11.36%	3.8%	162
14	12-13%	12.60%	0.3%	11
15	≥13%			
Weighted Average		**8.78%**		

Table 8H.5.14 Investor-Owned Utility Sector Discount Rate Distribution

Bin	Bin Range	Rates	Distribution (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.48%	1.4%	29
6	4-5%	4.72%	10.1%	216
7	5-6%	5.61%	37.6%	802
8	6-7%	6.42%	36.6%	781
9	7-8%	7.29%	6.8%	146
10	8-9%	8.55%	3.6%	77
11	9-10%	9.42%	3.8%	81
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.15%**		

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APPENDIX 8I. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR POOL HEATERS

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APPENDIX 8I. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR POOL HEATERS

8I.1 INTRODUCTION

This appendix presents life-cycle cost (LCC) results using energy price projections from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration (EIA)'s *Annual Energy Outlook 2022* (*AEO 2022*).[1]

This appendix describes the High and Low Economic Growth scenarios in further detail. See appendix 8A for details about how to generate LCC results for High Economic Growth and Low Economic Growth scenarios using the LCC spreadsheet.

8I.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate LCC results reported in chapter 8, DOE uses the Reference case energy price projections from *AEO 2022*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. For *AEO 2022*, EIA explored the impacts of alternative assumptions in other scenarios with different macroeconomic growth rates, world oil prices, rates of technology progress, and policy changes.

To reflect uncertainty in the projection of U.S. economic growth, EIA's *AEO 2022* uses High and Low Economic Growth scenarios to project the possible impacts of alternative economic growth assumptions on energy markets. The High Economic Growth scenario incorporates population, labor force and productivity growth rates that are higher than the Reference scenario, while these values are lower for the Low Economic Growth scenario. Economic output as measured by real GDP increases by 2.2 percent per year from 2021 through 2050, in the Reference case, 1.8 percent per year in the Low Economic Growth case, and 2.7 percent per year in the High Economic Growth case.

In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario than they are in the Reference Case. The energy price forecasts affect the operating cost savings at different efficiency levels. Figure 8K.2.1 through Figure 8K.2.3 show the national residential energy price trends for the Reference, High Economic Growth, and Low Economic Growth scenarios. Note that the data before 2050 (inclusive) is from AEO, whereas the data after 2050 uses a 5-yearge growth AEO data from 2046 to 2050. The limit of 2050 is marked with a vertical blue line in the charts.

Because *AEO 2022* provides the price trends by census division, each sampled household is matched to the appropriate census division price trend. See appendix 8E for details about how energy price trends by census division are applied in the LCC analysis.

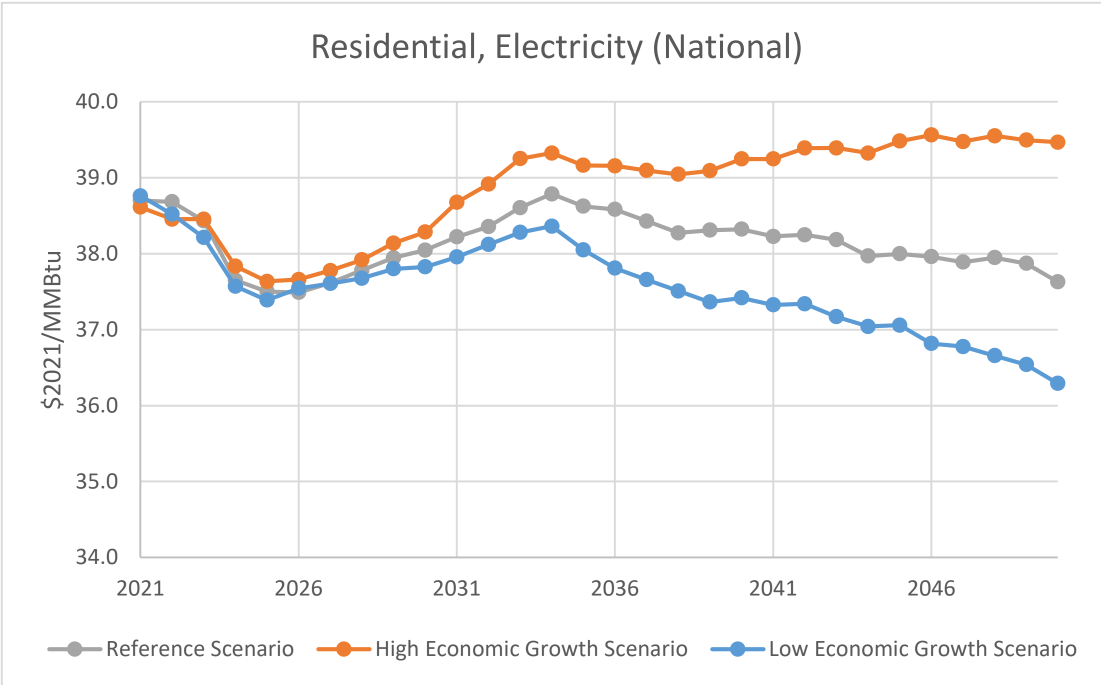

Figure 8I.2.1 Electricity Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

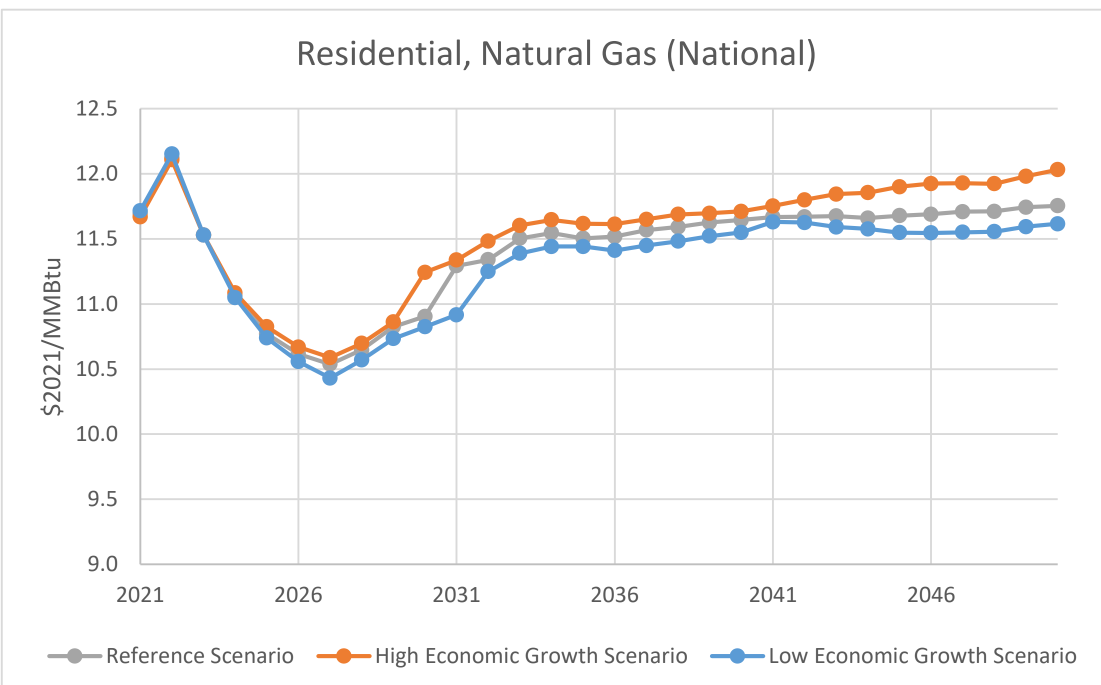

Figure 8I.2.2 Natural Gas Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

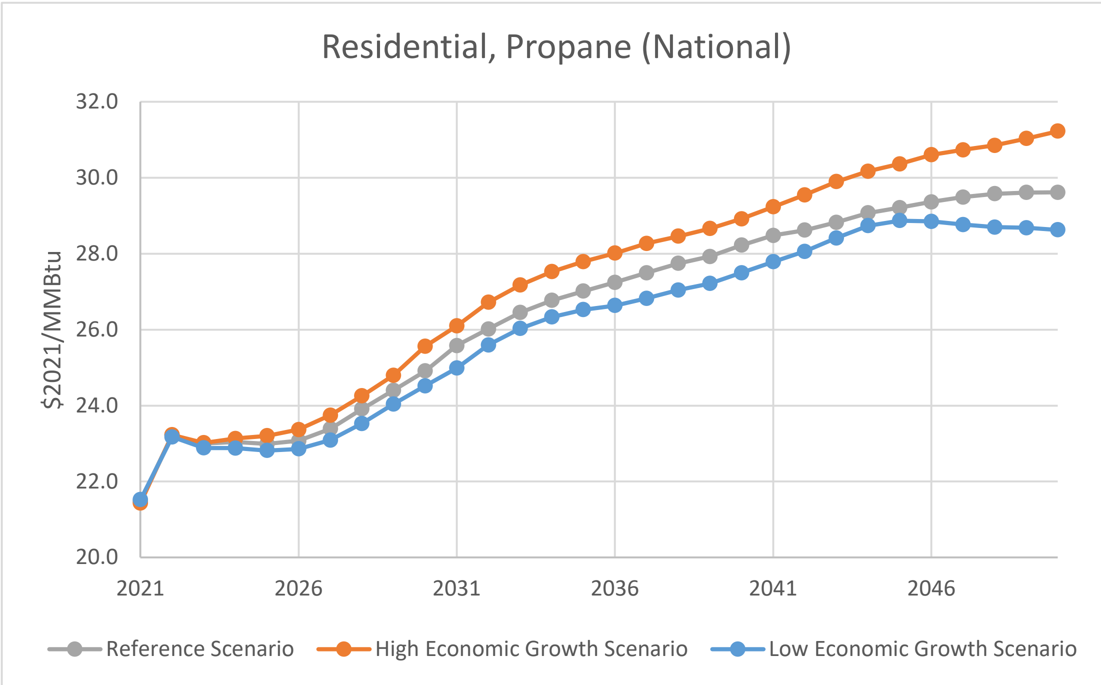

Figure 8I.2.3 LPG Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

8I.3 RESULTS

8I.3.1 Electric Pool Heaters

Table 8I.3.1 and Table 8I.3.2 summarize the LCC and PBP results for electric pool heaters for high economic growth scenario. Table 8I.3.3 and Table 8I.3.4 summarize the LCC and PBP results for electric pool heaters for low economic growth scenario.

Table 8I.3.1 Average LCC and PBP Results by Efficiency Level for Electric Pool Heaters for High Economic Growth

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99	3,214	1,758	15,996	19,210	NA	10.6
1	342	3,974	509	4,704	8,678	0.6	10.6
2	483	4,063	424	3,943	8,007	0.6	10.6
3	534	4,140	393	3,670	7,810	0.7	10.6
4	551	4,196	384	3,587	7,783	0.7	10.6
5	595	4,342	368	3,437	7,779	0.8	10.6

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8I.3.2 LCC Savings Relative to the Base Case Efficiency Distribution for Electric Pool Heaters for High Economic Growth

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	99	NA	0.0
1	342	8,206	0.4
2	483	3,794	0.9
3	534	1,154	10.5
4	551	1,059	20.2
5	595	960	37.0

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 8I.3.3 Average LCC and PBP Results by Efficiency Level for Electric Pool Heaters for Low Economic Growth

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	99	3,214	1,714	15,422	18,636	NA	10.6
1	342	3,974	497	4,559	8,533	0.6	10.6
2	483	4,063	415	3,827	7,891	0.7	10.6
3	534	4,140	385	3,564	7,704	0.7	10.6
4	551	4,196	376	3,485	7,680	0.7	10.6
5	595	4,342	360	3,340	7,682	0.8	10.6

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8I.3.4 LCC Savings Relative to the Base Case Efficiency Distribution for Electric Pool Heaters for Low Economic Growth

Efficiency Level	TE_i %	Average LCC Savings* *2020$*	% of Consumers that Experience Net Cost
0	99	NA	0.0
1	342	7,876	0.4
2	483	3,640	0.9
3	534	1,105	11.4
4	551	1,012	21.3
5	595	912	38.4

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

8I.3.2 Gas-fired Pool Heaters

Table 8I.3.5 and Table 8I.3.6 summarize the LCC and PBP results for gas-fired pool heaters for high economic growth scenario. Table 8I.3.7 and Table 8I.3.8 summarize the LCC and PBP results for gas-fired pool heaters for low economic growth scenario.

Table 8I.3.5 Average LCC and PBP Results by Efficiency Level for Gas-fired Pool Heaters for High Economic Growth

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	69.7	2,870	1,019	9,817	12,687	NA	10.6
1	81.3	2,881	902	8,619	11,500	0.1	10.6
2	83.3	3,059	889	8,500	11,560	1.5	10.6
3	94.7	3,749	814	7,816	11,565	4.3	10.6

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8I.3.6 LCC Savings Relative to the Base Case Efficiency Distribution for Gas-fired Pool Heaters for High Economic Growth

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	69.7	NA	0.0
1	81.3	1,136	0.0
2	83.3	53	31.6
3	94.7	16	69.0

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 8I.3.7 Average LCC and PBP Results by Efficiency Level for Gas-fired Pool Heaters for Low Economic Growth

Efficiency Level	TE_i %	Average Costs *2021$*				Simple Payback years	Average Lifetime years
		Installed Cost	First Year's Operating Cost	Lifetime Operating Cost	LCC		
0	69.7	2,870	978	9,276	12,145	NA	10.6
1	81.3	2,881	868	8,174	11,055	0.1	10.6
2	83.3	3,059	856	8,065	11,124	1.5	10.6
3	94.7	3,749	785	7,429	11,178	4.5	10.6

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8I.3.8 LCC Savings Relative to the Base Case Efficiency Distribution for Gas-fired Pool Heaters for Low Economic Growth

Efficiency Level	TE_i %	Average LCC Savings* *2021$*	% of Consumers that Experience Net Cost
0	69.7	NA	0.0
1	81.3	1,043	0.0
2	83.3	35	32.1
3	94.7	(41)	71.0

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

8I.3.3 Comparison of Reference, High Economic, and Low Economic Growth Scenarios

Table 8I.3.9 and Table 8I.3.10 compare the LCC savings and simple payback period for the considered AEO 2021 economic scenarios gas-fired pool heaters and electric pool heaters, respectively.

Table 8I.3.9 Results Comparison of Average LCC Savings and PBP for Economic Growth Scenarios for Electric Pool Heaters

Efficiency Level	TE_i %	Average Life-Cycle Cost Savings* *2021$*			Simple Payback Period *years*		
		High Economic Scenario	Low Economic Scenario	Reference Case	High Economic Scenario	Low Economic Scenario	Reference Case
1	342	8,206	7,876	7,995	0.6	0.6	0.6
2	483	3,794	3,640	3,695	0.6	0.7	0.6
3	534	1,154	1,105	1,123	0.7	0.7	0.7
4	551	1,059	1,012	1,029	0.7	0.7	0.7
5	595	960	912	929	0.8	0.8	0.8

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.
* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

Table 8I.3.10 Results Comparison of Average LCC Savings and PBP for Economic Growth Scenarios Gas-fired Pool Heaters

Efficiency Level	TE_i %	Average Life-Cycle Cost Savings* *2021$*			Simple Payback Period *years*		
		High Economic Scenario	Low Economic Scenario	Reference Case	High Economic Scenario	Low Economic Scenario	Reference Case
1	81.3	1,136	1,043	1,085	0.1	0.1	0.1
2	83.3	53	35	43	1.5	1.5	1.5
3	94.7	16	(41)	(15)	4.3	4.5	4.4

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.
* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALSIS SPREADSHEET MODEL

10A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel® spreadsheets accessible on the Internet from the Department of Energy's (DOE)'s consumer pool heaters rulemaking page: www1.eere.energy.gov/buildings/appliance_standards/standards.aspx?productid=44. From that page, follow the links to the final rule phase of the rulemaking and then to the analytical tools.

10A.2 STARTUP

The NIA spreadsheets enable the user to perform a National Impact Analysis (NIA) for consumer pool heaters (PHs). To utilize the spreadsheet, the Department assumed that the user would have access to a personal computer (PC) with a hardware configuration capable of running Windows 10 or later. To use the NIA spreadsheets, the user requires Microsoft Excel® 2013 or later installed under the Windows operating system.

10A.3 DESCRIPTION OF NATIONAL IMPACT ANALYSIS WORKSHEETS

The NIA spreadsheets perform calculations to project the change in national energy use and net present value of financial impacts due to revised energy efficiency standards. The energy use and associated costs for a given standard level are determined by calculating the shipments and then calculating the energy use and costs for all pool heaters shipped under that standard. The differences between the standards and base case can then be compared and the overall energy savings and net present values (NPV) determined. The NIA spreadsheets consist of the following major worksheets as shown in Table 10A.3.1.

Table 10A.3.1 Description of NIA Spreadsheet Worksheets

Worksheet	Description
Introduction	Contains an introduction to each worksheet and a flow chart of spreadsheet inputs and outputs.
Summary Result	Contains a summary of NIA results for all product classes.
Electric PH (baseline)	Contains baseline electric PH NIA calculations.
Electric PH (efficient)	Contains efficient electric PH NIA calculations.
Gas PH (baseline)	Contains baseline gas-fired PH NIA calculations.
Gas PH (efficient)	Contains efficient gas-fired PH NIA calculations.
PC Inputs	Contains energy use, electricity use, retail price, installation cost, and annual repair and maintenance costs for each efficiency level.
Shipments	Contains historical and projected shipments data for each product class.
Hist Shipments	Contains historical shipments data for each product class.
Price Indices	Contains the learning multipliers to adjust the manufacturer's cost over the entire analysis period.
Energy Factors	Contains energy conversion factors for NIA calculations.
Energy Price	Contains energy prices for each product class by year.
Lifetime	Includes the lifetime and the retirement function for each product class.
Supplementary Worksheets	Worksheets for labels and definitions used throughout the spreadsheets and downstream analysis.

10A.4 BASIC INSTRUCTIONS FOR OPERATING THE NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheet file has been downloaded from the Department's web site, open the file using MS Excel. Click "Enable Editing" when prompted and then click on the tab for the worksheet User Inputs.

2. Use MS Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user can change the parameters in the sheet "Summary Result". The default parameters (shown in Figure 10A.4.1) are:

Economic Growth	Reference
Analysis Period	Full
Rebound	Yes
Price Trend	Ref

Compliance Year	2028
Number of Years	30

Generate analysis results

Figure 10A.4.1 Default User Input Parameters (Summary) for NIA Spreadsheets

a) Economic Growth: Set to "Reference". To change value, click on the drop down menu next to cell "Economic Growth" and change to desired scenario ("Reference", "High", or "Low").

b) Analysis Period: Set to "Full". To change value, click on the drop down menu next to the cell "Analysis Period" and change to desired analysis period ("Full" (30 years) or "Short" (9 years)).

c) Rebound: Set to "Yes". To change value, click on the drop down menu next to the cell "Rebound" and change to desired value ("Yes" or "No").

d) Price Trend: Set to "Ref" (Reference). To change value, click on the drop down menu next to cell "Price Trend" and change to desired scenario ("Ref" (Reference), "Low", or "High").

4. The user can click the "Generate analysis results" button to generate summarized analysis results.

5. The user can view the summarized results (energy savings and NPV) in the "Summary Result" sheet (one example is shown in Figure 10A.4.2).

National Energy Savings (NES)

Cumulative Site NES for Consumer Pool Heaters; 30 Years of Shipments, 2028-2057 (Quads)

Product Class	TSL					
	1	2	3	4	5	6
Electric Pool Heater	0.08	0.10	0.14	0.15	0.15	0.17
Gas-fired Pool Heater	0.02	0.02	0.02	0.02	0.28	2.59
Total	0.10	0.12	0.16	0.17	0.43	2.76

Cumulative Primary NES for Consumer Pool Heaters; 30 Years of Shipments, 2028-2057 (Quads)

Product Class	TSL					
	1	2	3	4	5	6
Electric Pool Heater	0.22	0.28	0.38	0.41	0.41	0.46
Gas-fired Pool Heater	0.02	0.02	0.02	0.02	0.27	2.60
Total	0.24	0.30	0.39	0.43	0.69	3.05

Cumulative Full-Fuel-Cycle NES for Consumer Pool Heaters; 30 Years of Shipments, 2028-2057 (Quads)

Product Class	TSL					
	1	2	3	4	5	6
Electric Pool Heater	0.23	0.29	0.39	0.43	0.43	0.47
Gas-fired Pool Heater	0.02	0.02	0.02	0.02	0.27	2.60
Total	0.25	0.31	0.41	0.45	0.70	3.07

Net Present Value (NPV)

Cumulative Consumer NPV for Consumer Pool Heaters, Discounted at 3 Percent (Billion 2021$)

Product Class	TSL					
	1	2	3	4	5	6
Electric Pool Heater	1.48	1.82	2.33	2.32	2.32	2.20
Gas-fired Pool Heater	0.12	0.12	0.12	0.12	0.68	7.41
Total	1.60	1.93	2.45	2.44	3.00	9.60

Cumulative Consumer NPV for Consumer Pool Heaters, Discounted at 7 Percent (Billion 2021$)

Product Class	TSL					
	1	2	3	4	5	6
Electric Pool Heater	0.64	0.78	0.99	0.96	0.96	0.87
Gas-fired Pool Heater	0.05	0.05	0.05	0.05	0.23	2.66
Total	0.70	0.84	1.04	1.01	1.18	3.53

Figure 10A.4.2 NIA Results Summary for Pool Heater Standards

Make sure that the spreadsheet is in automatic calculation mode. The calculation mode could be changed by (shown in Figure 10A.4.3):

1. In Excel 2013 and later, go to the tab "Formulas" in the Office ribbon.
2. Click on the button "Calculation Options" and select "Automatic".

The results are automatically updated and are reported in the source energy savings matrix, net present value matrix, and summary table for each product class.

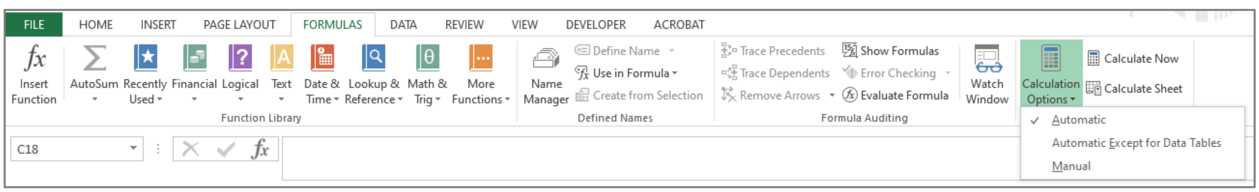

Figure 10A.4.3 Set the Spreadsheet to Automatic Calculation Mode

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APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the estimated full-fuel-cycle (FFC) energy savings from potential energy conservation standards. The FFC measure includes point-of-use (site) energy; the energy losses associated with generation, transmission, and distribution of electricity; and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's method of analysis previously encompassed only site energy and the energy lost through generation, transmission, and distribution of electricity. In 2011 DOE announced its intention, based on recommendations from the National Academy of Sciences, to use FFC measures of energy use and emissions when analyzing proposed energy conservation standards.[1] This appendix summarizes the methods DOE used to incorporate impacts of the full fuel cycle into the analysis.

In the national energy savings calculation, DOE estimates the site, primary and full-fuel-cycle (FFC) energy consumption for each standard level, for each year in the analysis period. DOE defines these quantities as follows:

- Site energy consumption is the physical quantity of fossil fuels or electricity consumed at the site where the end-use service is provided.[a] The site energy consumption is used to calculate the energy cost input to the net present value (NPV) calculation.
- Primary energy consumption is defined by converting the site fuel use from physical units, for example cubic feet for natural gas, or kWh for electricity, to common energy units (million Btu or MMBtu). For electricity the conversion factor is a marginal heat rate that incorporates losses in generation, transmission and distribution, and depends on the sector, end use and year.
- The full-fuel-cycle (FFC) energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use.

For electricity from the grid, site energy is measured in terawatt-hours (TWh). The primary energy of a unit of grid electricity is equal to the heat content of the fuels used to generate that electricity, including transmission and distribution losses.[b] DOE typically measures the primary energy associated with the power sector in quads (quadrillion Btu). Both primary fuels and electricity are used in upstream activities. The treatment of electricity in full-fuel-cycle analysis must distinguish between electricity generated by fossil fuels and electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates

[a] For fossil fuels, this is the site of combustion of the fuel.
[b] For electricity sources like nuclear energy and renewable energy, the primary energy is calculated using the EIA convention as described below.

to the fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

10B.2 SITE-TO-PRIMARY ENERGY FACTORS

DOE uses heat rates to convert site electricity savings in TWh to primary energy savings in quads. The heat rates are developed as a function of the sector, end-use and year of the analysis period. For this analysis DOE uses output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[2] EIA uses the NEMS model to produce the *Annual Energy Outlook* (*AEO*). DOE's approach uses the most recently available edition, in this case *AEO 2022*.[3] The *AEO* publication includes a reference case and a series of side cases incorporating different economic and policy scenarios. DOE calculates marginal heat rates as the ratio of the change in fuel consumption to the change in generation for each fossil fuel type, where the change is defined as the difference between the reference case and the side case. DOE calculates a marginal heat rate for each of the principal fuel types: coal, natural gas and oil. DOE uses the EIA convention of assigning a heat rate of 10.5 Btu/Wh to nuclear power and 9.5 Btu/Wh to electricity from renewable sources.

DOE multiplied the fuel share weights for sector and end-use by the fuel specific marginal heat rates, and summed over all fuel types, to define a heat rate for each sector/end-use. This step incorporates the transmission and distribution losses. In equation form:

$$h(u,y) = (1 + TDLoss)*\sum_{r,f} g(r,f,y)\, H(f,y)$$

Where:

$TDLoss$ = the fraction of total generation that is lost in transmission and distribution, equal to 0.07037
u = an index representing the sector/end-use (e.g. commercial cooling)
y = the analysis year
f = the fuel type
$H(f,y)$ = the fuel-specific heat rate
$g(r,f,y)$ = the fraction of generation provided by fuel type f for end-use u in year y
$h(u,y)$ = the end-use specific marginal heat rate

The sector/end-use specific heat rates are shown in Table 10B.2.1. These heat rates convert site electricity to primary energy in quads; *i.e.,* the units used in the table are quads per TWh.

Table 10B.2.1 Electric Power Heat Rates (MMBtu/MWh) by Sector and End-Use

	2025	2030	2035	2040	2045	2050+
Residential						
Clothes Dryers	9.591	9.390	9.339	9.283	9.225	9.225
Cooking	9.577	9.375	9.325	9.270	9.212	9.213
Freezers	9.606	9.403	9.349	9.290	9.231	9.231
Lighting	9.620	9.426	9.376	9.320	9.261	9.261
Refrigeration	9.605	9.403	9.349	9.291	9.231	9.231
Space Cooling	9.497	9.266	9.202	9.143	9.086	9.086
Space Heating	9.637	9.446	9.397	9.340	9.281	9.281
Water Heating	9.599	9.403	9.354	9.299	9.241	9.242
Other Uses	9.590	9.390	9.340	9.284	9.226	9.226
Commercial						
Cooking	9.500	9.296	9.253	9.203	9.150	9.152
Lighting	9.521	9.317	9.272	9.220	9.166	9.168
Office Equipment (Non-Pc)	9.460	9.250	9.208	9.159	9.107	9.110
Office Equipment (Pc)	9.460	9.250	9.208	9.159	9.107	9.110
Refrigeration	9.580	9.379	9.330	9.275	9.217	9.218
Space Cooling	9.474	9.240	9.178	9.119	9.063	9.063
Space Heating	9.645	9.454	9.404	9.347	9.287	9.287
Ventilation	9.582	9.382	9.333	9.278	9.220	9.221
Water Heating	9.499	9.296	9.254	9.205	9.151	9.154
Other Uses	9.477	9.269	9.226	9.177	9.125	9.127
Industrial						
All Uses	9.477	9.269	9.226	9.177	9.125	9.127

10B.3 FFC METHODOLOGY

The methods used to calculate FFC energy use are summarized here. The mathematical approach to determining FCC is discussed in Coughlin (2012).[4] Details related to the modeling of the fuel production chain are presented in Coughlin (2013).[5]

When all energy quantities are normalized to the same units, FFC energy use can be represented as the product of the primary energy use and an FFC multiplier. Mathematically the FFC multiplier is a function of a set of parameters that represent the energy intensity and material losses at each stage of energy production. Those parameters depend only on physical data, so the calculations require no assumptions about prices or other economic factors. Although the parameter values may differ by geographic region, this analysis utilizes national averages.

The fuel cycle parameters are defined as follows.

- a_x is the quantity of fuel *x* burned per unit of electricity produced for grid electricity. The calculation of a_x includes a factor to account for losses incurred through the transmission and distribution systems.

- b_y is the amount of grid electricity used in producing fuel *y*, in MWh per physical unit of fuel *y*.
- c_{xy} is the amount of fuel *x* consumed in producing one unit of fuel *y*.
- q_x is the heat content of fuel *x* (MBtu/physical unit).

All the parameters are calculated as functions of an annual time step; hence, when evaluating the effects of potential new standards, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period and cumulatively.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. Also calculated is a multiplier for electricity that reflects the fuel mix used in its generation. The multipliers are dimensionless numbers applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

The method for performing the full-fuel-cycle analysis utilizes data and projections published in the *AEO 2022*. Table 10B.3.1 summarizes the data used as inputs to the calculation of various parameters. The column titled "*AEO* Table" gives the name of the table that provided the reference data.

Table 10B.3.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter(s)	Fuel(s)	*AEO* Table	Variables
q_x	All	Conversion factors	MMBtu per physical unit
a_x	All	Electricity supply, disposition, prices, and emissions Energy consumption by sector and source	Generation by fuel type Electric energy consumption by the power sector
b_c, c_{nc}, c_{pc}	Coal	Coal production by region and type	Coal production by type and sulfur content
b_p, c_{np}, c_{pp}	Petroleum	Refining industry energy consumption Liquid fuels supply and disposition International liquids supply and disposition Oil and gas supply	Refining-only energy use Crude supply by source Crude oil imports Domestic crude oil production
c_{nn}	Natural gas	Oil and gas supply Natural gas supply, disposition, and prices	U.S. dry gas production Pipeline, lease, and plant fuel
z_x	All	Electricity supply, disposition, prices, and emissions	Power sector emissions

The *AEO 2022* does not provide all the information needed to estimate total energy use in the fuel production chain. Coughlin (2013) describes the additional data sources needed to complete the analysis. The time dependence in the FFC multipliers, however, arises exclusively from variables taken from the *AEO*.

10B.4 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.4.1. The 2050 value was held constant for the analysis period beyond 2050, which is the last year in the *AEO 2022* projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

Table 10B.4.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO 2022*)

	2025	2030	2035	2040	2045	2050+
Electricity (grid)	1.044	1.041	1.039	1.039	1.039	1.039

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APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

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APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

10C.1 INTRODUCTION

DOE investigated the impact of different product price trends on the net present value (NPV) for the considered TSLs for electric pool heaters (EPHs), heat pump pool heaters and gas-fired pool heaters (GPHs). The NPV results presented in chapter 10 are based on a default product price trend for each product type.

DOE did not find any historical producer price indices (PPI) for pool heaters to study the historical price trend for pool heaters. DOE examines historical distributor prices for pool heaters at different ratings spanning the time period 2003-2021 from the 2022 Pkdata.[1] For this product, DOE found consistent negative real price trends. Therefore, DOE concluded that the real prices of pool heaters have a different long term trend than prices in the economy as a whole. In this analysis, DOE concluded that the manufacturer selling prices of products meeting various efficiency levels may not remain fixed, in real terms, after 2021 (the year for which the engineering analysis estimated costs).

DOE considered two price trend sensitivities: (1) a decreasing price trend scenario and (2) an increasing price trend scenario. The derivation of these two alternative price trend scenarios are carefully explained in Appendix 8C, and the results of the estimated learning rate in each price trend scenario are summarized in Table 10C.1.1.

Table 10C.1.1 Price Trend Sensitivities

Sensitivity	Price Trend	Estimated Annual Rate Change %		
		Electric PHs	Heat Pump PHs	Gas PHs
Constant Price Trend Scenario	Constant price projection	0.00	0.00	0.00
Decreasing Price Trend Scenario	Exponential fit to the PKData from 2003 to 2014	0.61	0.64	0.58
Increasing Price Trend Scenario	Mirror image of Exponential fit to the PKData from 2003 to 2014	-0.61	-0.64	-0.58

10C.2 NET PRESENT VALUE RESULTS USING ALTERNATIVE PRODUCT PRICE TRENDS

This section presents the NPV results using the alternative product price forecast for each key product class. Table 10C.2.4 compares the total (all classes) NPV using the default product price forecast with the NPV using the alternative product price forecasts. With the high decreasing price trend scenario, the NPV for the highest TSLs rises substantially compared with the reference case; in contrast, it declines with the no price trend scenario.

Table 10C.2.1 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Using Reference Product Price Trend; 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.48	1.82	2.33	2.32	2.32	2.20
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.68	7.41
	Total	**1.60**	**1.93**	**2.45**	**2.44**	**3.00**	**9.60**
7 percent	Electric Pool Heaters	0.64	0.78	0.99	0.96	0.96	0.87
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.23	2.66
	Total	**0.70**	**0.84**	**1.04**	**1.01**	**1.18**	**3.53**

Note: Numbers may not add to totals, due to rounding.

Table 10C.2.2 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Alternative Product Price Trend (Decreasing Price Trend Scenario); 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.49	1.83	2.36	2.37	2.37	2.28
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.73	7.74
	Total	**1.60**	**1.94**	**2.47**	**2.48**	**3.09**	**10.02**
7 percent	Electric Pool Heaters	0.65	0.79	1.00	0.98	0.98	0.90
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.25	2.79
	Total	**0.70**	**0.84**	**1.05**	**1.03**	**1.22**	**3.70**

Table 10C.2.3 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Alternative Product Price Trend (Increasing Price Trend Scenario); 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.47	1.81	2.31	2.27	2.27	2.12
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.63	7.07
	Total	**1.59**	**1.92**	**2.42**	**2.39**	**2.90**	**9.19**
7 percent	Electric Pool Heaters	0.64	0.78	0.98	0.94	0.94	0.84
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.21	2.52
	Total	**0.69**	**0.83**	**1.03**	**0.99**	**1.14**	**3.36**

Table 10C.2.4 Comparison of Total Net Present Value (NPV) Across All Product Classes for Alternative Product Price Trends

Discount Rate	Price Trend Scenario	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3%	Reference Case (Constant Trend)	1.60	1.93	2.45	2.44	3.00	9.60
	Decreasing Price Trend	1.60	1.94	2.47	2.48	3.09	10.02
	Increasing Price Trend	1.59	1.92	2.42	2.39	2.90	9.19
7%	Reference Case (Constant Trend)	0.70	0.84	1.04	1.01	1.18	3.53
	Decreasing Price Trend	0.70	0.84	1.05	1.03	1.22	3.70
	Increasing Price Trend	0.69	0.83	1.03	0.99	1.14	3.36

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APPENDIX 10D. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR CONSUMER POOL HEATERS

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APPENDIX 10D. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR CONSUMER POOL HEATERS

10D.1 INTRODUCTION

This appendix presents National Impact Analysis (NIA) results using energy price forecasts from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration's (EIA's) *Annual Energy Outlook 2022* (*AEO 2022*).[1] To estimate energy prices after 2050 in the high and low scenarios, DOE used the average growth rate between 2046 and 2050. See appendix 8I for details about alternative economic growth scenarios.

This appendix also describes the High and Low Economic Growth scenarios in further detail. See appendix 10A for details about how to generate NIA results for High Economic Growth and Low Economic Growth scenarios using the NIA spreadsheet.

10D.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate NIA results reported in chapter 10, DOE uses the Reference case energy price and housing projections from *AEO 2022*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. To reflect uncertainty in the future of U.S. economic growth, *AEO 2022* uses High and Low Economic Growth scenarios to project the possible impacts on energy markets of alternative assumptions for macroeconomic growth rates.[2] In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario. See appendix 8I for details about the effect of these alternative economic scenarios on energy prices.

Because *AEO 2022* provides the price trends by census division, each sampled household is matched to the appropriate census division price trend. See chapter 10 for details about how energy price trends by census division are applied in the NIA analysis.

In addition, the High and Low Economic Growth scenarios provide different housing starts projections that affect the pool heater shipments projections. Figure 10D.2.1 shows the electric pool heaters (PHs) shipment projections based on the different *AEO 2022* scenarios, and Figure 10D.2.2 shows the gas-fired PHs shipment projections based on the different *AEO 2022* scenarios.

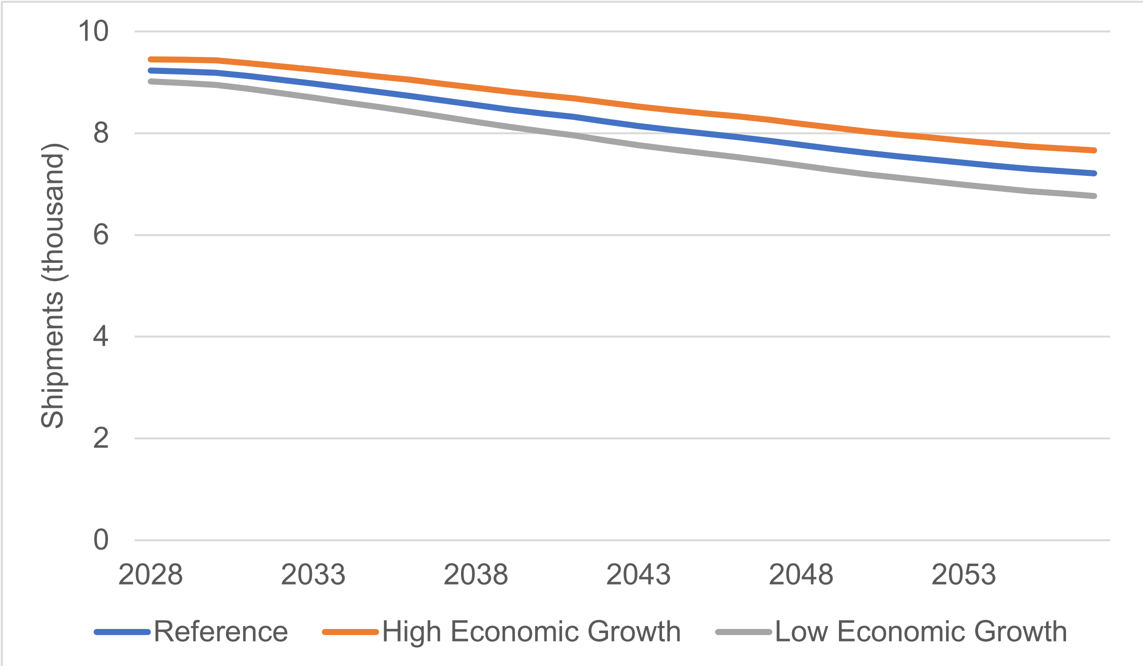

Figure 10D.2.1 Electric PHs Shipment Projections for Reference Case and High and Low Economic Growth Scenarios (No-New-Standards Case)

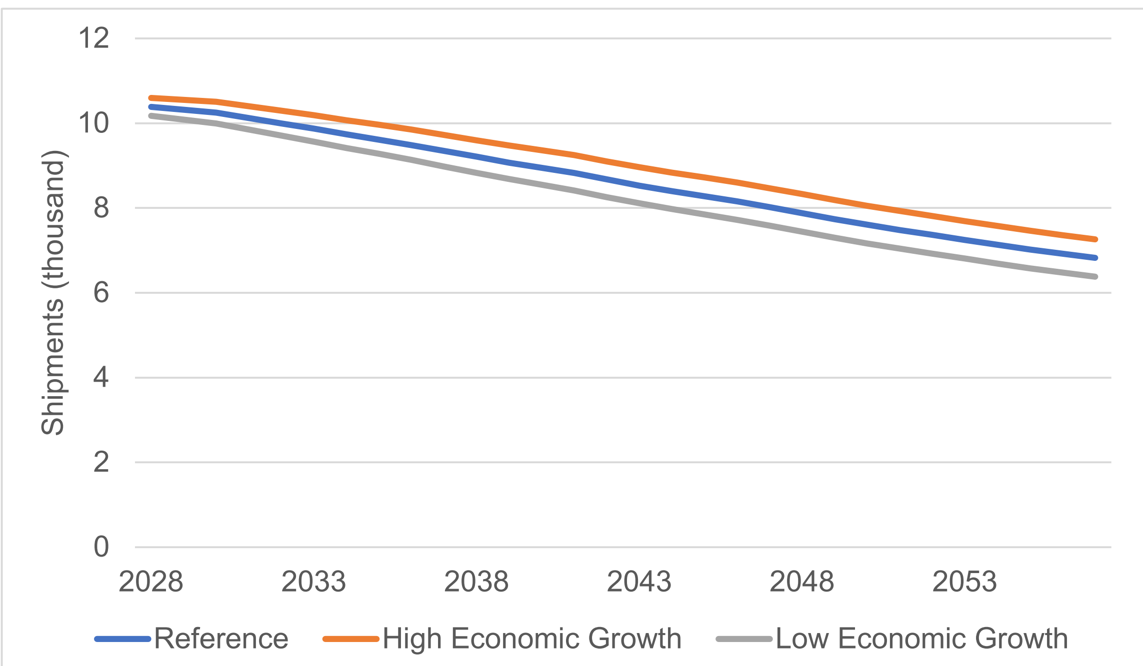

Figure 10D.2.2 Gas-fired PHs Shipment Projections for Reference Case and High and Low Economic Growth Scenarios (No-New-Standards Case)

10D.3 RESULTS

This section presents the national energy savings (NES) and national present value (NPV) results for the considered trial standard levels (TSLs) for electric and gas-fired pool heaters using the Reference Case, High Economic Growth, and Low Economic Growth scenarios. The results include the impacts of the fuel switching estimated to occur under each standards case.

10D.3.1 National Energy Savings

For AFUE standards, Table 10D.3.1 through Table 10D.3.3 show the NES results for each TSL analyzed for EPHs and GPHs under different economic growth scenarios.

Table 10D.3.1 National Energy Savings (Full Fuel Cycle) – Reference Case

Product Class	Trial Standard Levels					
	1	2	3	4	5	6
	quads					
Electric Pool Heaters	0.23	0.29	0.39	0.43	0.43	0.47
Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.27	2.60
Total	**0.25**	**0.31**	**0.41**	**0.45**	**0.70**	**3.07**

Table 10D.3.2 National Energy Savings (Full Fuel Cycle) – High Economic Growth

Product Class	Trial Standard Levels					
	1	2	3	4	5	6
	quads					
Electric Pool Heaters	0.24	0.30	0.40	0.45	0.45	0.49
Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.28	2.68
Total	**0.26**	**0.32**	**0.42**	**0.47**	**0.73**	**3.17**

Table 10D.3.3 National Energy Savings (Full Fuel Cycle) – Low Economic Growth

Product Class	Trial Standard Levels					
	1	2	3	4	5	6
	quads					
Electric Pool Heaters	0.23	0.28	0.38	0.41	0.41	0.46
Gas-fired Pool Heaters	0.02	0.02	0.02	0.02	0.26	2.51
Total	**0.25**	**0.30**	**0.39**	**0.43**	**0.68**	**2.97**

10D.3.2 Net Present Value of Consumer Impacts

For AFUE standards, Table 10D.3.4 through Table 10D.3.6 show the NPV results for each of the TSLs analyzed for EPHs and GPHs under different economic growth scenarios. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10D.3.4 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Using Reference Case; 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.48	1.82	2.33	2.32	2.32	2.20
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.68	7.41
	Total	**1.60**	**1.93**	**2.45**	**2.44**	**3.00**	**9.60**
7 percent	Electric Pool Heaters	0.64	0.78	0.99	0.96	0.96	0.87
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.23	2.66
	Total	**0.70**	**0.84**	**1.04**	**1.01**	**1.18**	**3.53**

Note: Numbers may not add to totals, due to rounding.

Table 10D.3.5 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Using High Economic Growth Case; 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.57	1.94	2.50	2.49	2.49	2.37
	Gas-fired Pool Heaters	0.12	0.12	0.12	0.12	0.73	7.91
	Total	**1.70**	**2.06**	**2.63**	**2.62**	**3.22**	**10.29**
7 percent	Electric Pool Heaters	0.68	0.83	1.05	1.02	1.02	0.93
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.24	2.81
	Total	**0.73**	**0.88**	**1.10**	**1.07**	**1.26**	**3.74**

Note: Numbers may not add to totals, due to rounding.

Table 10D.3.6 Cumulative Net Present Value of Consumer Benefits for Consumer Pool Heaters Using Low Economic Growth Case; 30 Years of Shipments (2028–2057)

Discount Rate	Product Class	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3 percent	Electric Pool Heaters	1.41	1.72	2.20	2.18	2.18	2.07
	Gas-fired Pool Heaters	0.11	0.11	0.11	0.11	0.64	7.03
	Total	**1.52**	**1.83**	**2.31**	**2.29**	**2.83**	**9.10**
7 percent	Electric Pool Heaters	0.62	0.75	0.94	0.91	0.91	0.82
	Gas-fired Pool Heaters	0.05	0.05	0.05	0.05	0.22	2.54
	Total	**0.66**	**0.80**	**0.98**	**0.96**	**1.12**	**3.36**

Note: Numbers may not add to totals, due to rounding.

10D.3.3 Summary

Table 10D.3.7 and Table 10D.3.8 show the NES and NPV results for PHs standards for each of the TSL under different economic growth scenarios. NES and NPV results are larger for High Economic Growth scenario and smaller for Low Economic Growth scenario compared to Reference Case.

Table 10D.3.7 Comparison of National Energy Savings Results for Reference Case and High and Low Economic Growth Scenarios

Scenarios	Trial Standard Level					
	1	2	3	4	5	6
	quads					
Reference Case	0.25	0.31	0.41	0.45	0.70	3.07
High Economic Growth	0.26	0.32	0.42	0.47	0.73	3.17
Low Economic Growth	0.25	0.30	0.39	0.43	0.68	2.97

Table 10D.3.8 Comparison of Net Present Value Results for Reference Case and High and Low Economic Growth Scenarios

Discount Rate	Scenario	Trial Standard Level					
		1	2	3	4	5	6
		billion 2021$					
3%	Reference Case	1.60	1.93	2.45	2.44	3.00	9.60
	High Economic Growth	1.70	2.06	2.63	2.62	3.22	10.29
	Low Economic Growth	1.52	1.83	2.31	2.29	2.83	9.10
7%	Reference Case	0.70	0.84	1.04	1.01	1.18	3.53
	High Economic Growth	0.73	0.88	1.10	1.07	1.26	3.74
	Low Economic Growth	0.66	0.80	0.98	0.96	1.12	3.36

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APPENDIX 10E. REBOUND EFFECT ANALYSIS

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APPENDIX 10E. REBOUND EFFECT ANALYSIS

10E.1 INTRODUCTION

As the energy efficiency of a product improves following an amended energy conservation standard, the cost of operating the unit, for the same amount of energy service, will decrease. The rebound effect describes a phenomenon where consumers increase their demand for the energy service as a result of this reduction in operating cost, leading to a decrease in potential energy savings. At the same time, consumers benefit from increased utilization of products due to rebound. Overall consumer welfare (taking into account additional costs and benefits) is generally understood to increase from rebound.

There are two main types of rebound effects in consumer theory: direct and indirect rebound effect.[1,2,3] The direct rebound effect measures the behavioral response directly attributed to the energy efficiency improvement. This approach treats an energy efficiency improvement as an exogenous effect while holding other product attributes constant (no change in the quality of the energy service). The indirect rebound effect, on the other hand, has a much broader scope which considers the substitution and income effect on other goods induced by the decline in price of a given energy service.

In monetizing the impact of the rebound effect, DOE focuses on the impact of the *direct* rebound effect in the net present value (NPV) calculation in the National Impact Analysis (NIA). In this appendix, DOE describes the conceptual theory and implementation of the calculation used to monetize the consumer welfare benefit from the rebound effect in the NIA.

10E.2 THE MICROECONOMIC THEORY

The direct rebound effect can be measured by the elasticity of demand for energy service (S), with respect to energy efficiency (ε), denoted as $\eta_{S,\varepsilon}$, or alternatively, the elasticity of demand for energy (E) with respect to energy efficiency (ε), denoted as $\eta_{E,\varepsilon}$.[2,4] Given the relationship between energy demand and energy service demand, $S = \varepsilon E$, it can be shown that:

$$\eta_{E,\varepsilon} = \frac{\partial E}{\partial \varepsilon}\frac{\varepsilon}{E} = \frac{\varepsilon}{E}\left(\frac{1}{\varepsilon}\frac{\partial S(\varepsilon)}{\partial \varepsilon} - \frac{1}{\varepsilon^2}S\right) = \frac{\partial S}{\partial \varepsilon}\frac{\varepsilon}{S} - 1 \equiv \eta_{S,\varepsilon} - 1$$

Eq. 10E.1

For example, a direct rebound effect of 20% implies that that a 10 percent increase in energy efficiency would result in a 2 percent increase in demand for energy service and also an 8 percent reduction in energy consumption. Alternatively speaking, a 20 percent of energy savings would be taken back compared to the expected 10 percent reduction in energy consumption if there was no increased demand in energy service following the improvement in energy efficiency (zero rebound).

Based on the framework proposed by Sorrell and Dimitropoulos (2008), the implicit price of energy service can be expressed as $P_s = {}^{P_E}/_{\varepsilon}$. From this it follows[5]:

$$\eta_{E,\varepsilon} = \frac{\partial E}{\partial \varepsilon}\frac{\varepsilon}{E} = \frac{\varepsilon}{E}\left(\frac{1}{\varepsilon}\frac{\partial S}{\partial P_S}\frac{\partial P_S}{\partial \varepsilon} - \frac{1}{\varepsilon^2}S\right) = \frac{\varepsilon}{E}\left(-\frac{\partial S}{\partial P_S}\frac{P_E}{\varepsilon^3} - \frac{1}{\varepsilon^2}S\right) = -\frac{\partial S}{\partial P_S}\frac{P_S}{S} - 1 \equiv -\eta_{S,P_S} - 1$$

Eq. 10E.2

Thus, the direct rebound effect, $\eta_{S,\varepsilon}$, can be approximated by $-\eta_{S,P_S}$, or the negative of the elasticity of demand for energy service (S) with respect to the price of energy service (P_S).

While the rebound effect may likely reduce the energy savings, the presence of rebound effect also has welfare implications on energy efficiency policies. Understanding the magnitude of the rebound effect and its energy savings and economic welfare implications helps evaluate the welfare effect of the energy efficiency policies on consumers.[6,7]

As energy efficiency improves, the price of energy service moves from P_S to P_S', and the change in consumer surplus can be illustrated as below:

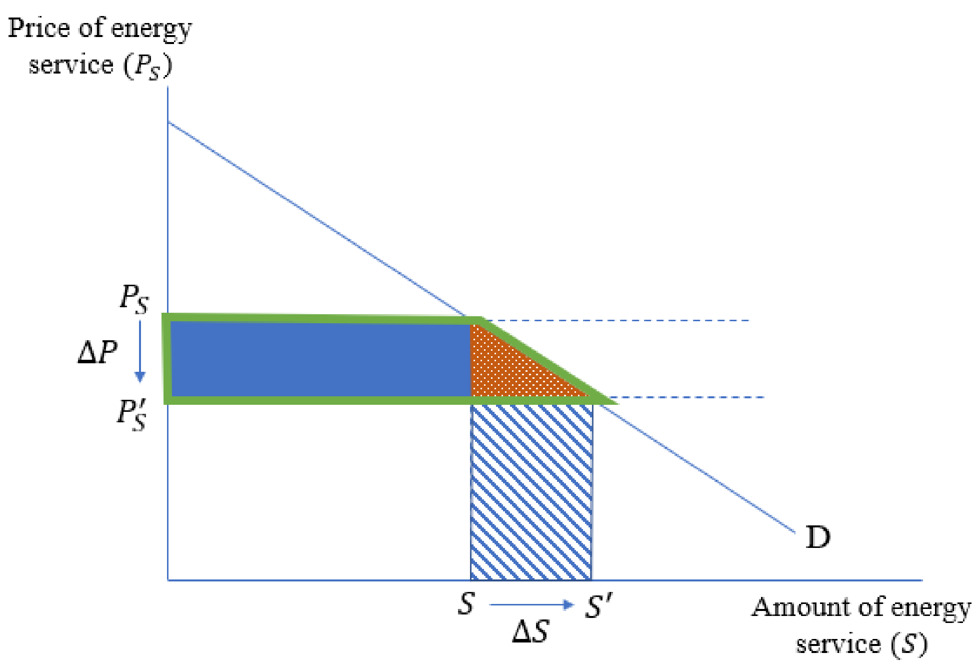

Figure 10E.2.1 The Consumer Surplus Illustration with Rebound Effect

The trapezoidal area outlined in green depicts the change in consumer surplus from improved energy efficiency (P_S to P_S') with rebound effect (S to S'). The solid blue rectangular area reflects the monetary savings from the decrease in energy service price while holding the level of energy service constant. The difference of the two areas, the orange triangle, represents the welfare gained from consuming additional energy service at the lower energy service price. All these areas are expressed in the unit of dollar.

In the context of pool heaters, the energy service (S) being provided is heating in terms of British Thermal Units (*Btus)* and the energy efficiency (ε) is approximated as the shipment-weighted annual fuel utilization efficiency (AFUE).

The change in the price of energy service, ΔP_S, expressed in units of *$/Btu* can be written as:

$$\Delta P_S = \frac{P_E}{1{,}000{,}000} \times \left(\frac{1}{SWAFUE_{NNS}(v)} - \frac{1}{SWAFUE_{STD}(v)}\right)$$

Eq. 10E.3

where,

P_E = weighted-average marginal natural gas price (*$/MMBtu*),
v = shipments vintage,
$SWAFUE_{NNS}$ = shipment-weighted AFUE in the no new standard case*,* and
$SWAFUE_{STD}$ = shipment-weighted AFUE in the standards case.

The change in the amount of heating service, ΔS, expressed in units of *Btu* can be written as:

$$\Delta S = \eta_{S,P_S} S_{NNS} \frac{\Delta P_S}{P_{s,NNS}}$$

Eq. 10E.4

where,

η_{S,P_S} = the price elasticity of energy service,
S_{NNS} = annual demand in heating energy service in the no-new-standards case *(Btu),*
ΔP_S = the change in the price of energy service *($/Btu),*
$P_{S,NNS}$ = the price of energy service in the no-new-standards case *($/Btu).*

To calculate the average consumer welfare benefit ($CW_{rebound}$) of the rebound (i.e., the orange triangle) in a given year for each unit shipped after the standard takes effect, DOE employs the following equation

$$\begin{aligned} CW_{Rebound}(v) &= \frac{1}{2}\Delta P_S \Delta S \\ &= \frac{1}{2}\frac{P_E}{1{,}000{,}000} SWAFUE_{NNS}(v) \\ &\quad \times \left(\frac{1}{SWAFUE_{NNS}(v)} - \frac{1}{SWAFUE_{STD}(v)}\right)^2 \eta_{S,P_S} S_{NNS} \end{aligned}$$

Eq. 10E.5

where,

$CW_{Rebound}(v)$ = the average consumer welfare benefit from the rebound effect for shipments vintage *v ($),*

P_E = weighted-average marginal natural gas price (*$/MMBtu*),
$v =$ shipments vintage,
$SWAFUE_{NNS}$ = shipment-weighted AFUE in the no new standard case,
$SWAFUE_{STD}$ = shipment-weighted AFUE in the standards case,
η_{S,P_S} = the price elasticity of energy service, and
S_{NNS} = annual demand in heating energy service in the no-new-standards case *(Btu)*.

10E.3 POOL HEATER DATA SOURCES

In order to calculate the triangular area shown in Figure 10G.1, one must first derive the slope of the energy service demand curve, or the price elasticity of energy service. DOE examined a 2009 review of empirical estimates of the rebound effect for various energy-using products.[4] This review concluded that the econometric and quasi-experimental studies suggest a mean value for the direct rebound effect for household heating of around 20 percent. DOE also examined a 2012 ACEEE paper[3] and a 2013 paper by Thomas and Azevedo.[2] Both of these publications examined the same studies that were reviewed by Sorrell, as well as Greening *et al.*,[8] and identified methodological problems with some of the studies. The studies believed to be most reliable by Thomas and Azevedo show a direct rebound effect for heating products in the 1-percent to 15-percent range, while Nadel concludes that a more likely range is 1 to 12 percent, with rebound effects sometimes higher for low-income households who could not afford to adequately heat their homes prior to weatherization. Based on DOE's review of these recent assessments, DOE used a 10-percent rebound effect for EPHs and GPHs in the residential applications for standards. However, for commercial applications, DOE applied no rebound effect, consistent with other recent energy conservation standards rulemakings.[9,10,11]

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12A. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

12A.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards on manufacturers of pool heaters. The basic mode of analysis is to estimate the change in the value of the industry or manufacturers following a regulation or a series of regulations. The model structure also allows an analysis of multiple products with regulations taking effect over a period of time, and of multiple regulations on the same products.

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (*i.e.*, the no-new-standards case) and under different trial standard levels (TSLs) (*i.e.*, the standards case).

Output from the model consists of summary financial metrics, graphs of major variables, and, when appropriate, access to the complete cash flow calculation.

12A.2 POOL HEATER DESCRIPTION

DOE analyzed the impacts of standards on pool heaters. The basic structure of the GRIM is a standard annual cash flow analysis that uses manufacturer selling prices, manufacturing costs, a shipments forecast, and financial parameters as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: income and cash flow. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. The line items below relate to the pool heater manufacturers and are definitions of listed items on the printout of the output sheet. Please refer to Figure 12A.2.1.

1) ***Revenues:*** Annual revenues - computed by multiplying products' unit prices at each efficiency level by the appropriate manufacturer markup;

2) ***Total Shipments:*** The total covered units shipped;

3) ***Materials:*** The portion of cost of goods sold (COGS) that includes materials;

4) ***Labor:*** The portion of COGS that includes direct labor, commissions, dismissal pay, bonuses, vacation, sick leave, social security contributions, fringe, and assembly labor up-time;

5) ***Depreciation:*** The portion of COGS that includes an allowance for the total amount of fixed assets used to produce that one unit;

6) ***Overhead:*** The portion of COGS that includes indirect labor, indirect material, energy use, maintenance, property taxes, and insurance related to assets;

7) ***Standard SG&A:*** Selling, general, and administrative costs are computed as a percentage of ***Revenues (1)***;

8) ***R&D:*** GRIM separately accounts for ordinary research and development (R&D) as a percentage of ***Revenues (1)***;

9) ***Product Conversion Costs:*** Product conversion costs are investments in research, development, testing, marketing, and other costs focused on making product designs comply with amended energy conservation standards. The GRIM allocates these costs over the period between the standards' announcement and compliance dates;

10) ***Stranded Assets:*** In the year the standard becomes effective, a one-time write-off of stranded assets is accounted for;

11) ***Earnings before Interest and Taxes (EBIT):*** Includes profits before deductions for interest paid and taxes;

12) ***Per Unit EBIT:*** The average amount of ***EBIT (11)*** per covered unit shipped;

13) ***EBIT/Revenues: EBIT (11)*** as a percentage of sales to compare with the industry's average reported in financial statements;

14) ***Taxes:*** Taxes on ***EBIT (11)*** are calculated by multiplying the tax rate contained in the Discounted Cash Flow tab by ***EBIT (11)***;

15) ***Net Operating Profits after Taxes (NOPAT):*** Computed by subtracting ***Taxes (14)*** from ***EBIT (11)***;

16) ***NOPAT repeated: NOPAT (15)*** is repeated in the Statement of Cash Flows;

17) ***Depreciation repeated: Depreciation (5)*** is added back in the Statement of Cash Flows because it is a non-cash expense;

18) ***Stranded Assets repeated: Stranded Assets (10)*** is added back in the Statement of Cash Flows because it is a non-cash expense;

19) ***Change in Working Capital:*** Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues;

20) ***Cash Flow from Operations:*** Calculated by taking ***NOPAT (16)***, adding back non-cash items such as ***Depreciation (17)*** and ***Stranded Assets (18)***, and subtracting the ***Change in Working Capital (19)***;

21) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of ***Revenues (1)***;

22) ***Capital Conversion Costs:*** Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new product designs can be fabricated and assembled under amended regulations; the GRIM allocates these costs over the period between the standards' announcement and compliance dates;

23) ***Free Cash Flow:*** Calculated by taking annual ***Cash Flow from Operations (20)*** and subtracting ***Ordinary Capital Expenditures (21)*** and ***Capital Conversion Costs (22)***;

24) ***Free Cash Flow repeated: Free Cash Flow (23)*** is repeated in the Discounted Cash Flow section;

25) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the ***Free Cash Flow (24)*** at the beginning of 2057 at a constant rate in perpetuity;

26) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future;

27) ***Discounted Cash Flow: Free Cash Flow (23)*** multiplied by the ***Present Value Factor (26)***. For the end of 2057, the discounted cash flow includes the discounted ***Terminal Value (25)***; and

28) ***Industry Value through the end of 2057:*** The sum of ***Discounted Cash Flows (27)***.

Industry Income Statement (in 2021$ millions)	2021	Reference Yr 2022	Ancmt Yr 2023	2024	2025	2026	2027	Std Yr 2028	2029	2030	2031
Revenues	$ 605.0	$ 611.5	$ 618.8	$ 626.6	$ 634.8	$ 643.1	$ 602.2	$ 613.5	$ 623.0	$ 632.4	$ 638.7
Shipping Cost	$ 27.8	$ 28.1	$ 28.4	$ 28.8	$ 29.2	$ 29.6	$ 27.6	$ 28.1	$ 28.6	$ 29.0	$ 29.3
Shipments	0.396	0.400	0.405	0.410	0.415	0.421	0.396	0.403	0.409	0.415	0.419
Revenue - Shipping	$ 577.2	$ 583.4	$ 590.4	$ 597.8	$ 605.6	$ 613.6	$ 574.6	$ 585.4	$ 594.4	$ 603.4	$ 609.4
- Materials	$ 334.5	$ 338.1	$ 342.1	$ 346.4	$ 350.9	$ 355.5	$ 332.2	$ 338.4	$ 343.7	$ 349.0	$ 352.6
- Labor	$ 37.5	$ 37.9	$ 38.4	$ 38.9	$ 39.4	$ 39.9	$ 37.6	$ 38.3	$ 38.9	$ 39.4	$ 39.8
- Depreciation	$ 11.2	$ 11.3	$ 11.4	$ 11.6	$ 11.7	$ 11.9	$ 11.2	$ 11.4	$ 11.6	$ 11.7	$ 11.9
- Overhead	$ 23.0	$ 23.2	$ 23.5	$ 23.8	$ 24.1	$ 24.4	$ 23.1	$ 23.5	$ 23.9	$ 24.2	$ 24.4
- Standard SG&A	$ 102.2	$ 103.3	$ 104.5	$ 105.8	$ 107.2	$ 108.6	$ 101.7	$ 103.6	$ 105.2	$ 106.8	$ 107.9
- R&D	$ 11.5	$ 11.7	$ 11.8	$ 12.0	$ 12.1	$ 12.3	$ 11.5	$ 11.7	$ 11.9	$ 12.1	$ 12.2
- Product Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 57.3	$ 58.0	$ 58.7	$ 59.4	$ 60.2	$ 61.0	$ 57.3	$ 58.4	$ 59.3	$ 60.1	$ 60.7
Per Unit EBIT *($/unit)*	$ 144.81	$ 144.83	$ 144.86	$ 144.89	$ 144.91	$ 144.93	$ 144.85	$ 144.87	$ 144.90	$ 144.94	$ 144.97
EBIT/Revenues (%)	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*	*9.5%*
- Taxes	$ 12.0	$ 12.2	$ 12.3	$ 12.5	$ 12.6	$ 12.8	$ 12.0	$ 12.3	$ 12.4	$ 12.6	$ 12.8
Net Operating Profit after Taxes (NOPAT)	**$ 45.3**	**$ 45.8**	**$ 46.3**	**$ 46.9**	**$ 47.6**	**$ 48.2**	**$ 45.3**	**$ 46.1**	**$ 46.8**	**$ 47.5**	**$ 48.0**
Cash Flow Statement											
NOPAT	$ 45.3	$ 45.8	$ 46.3	$ 46.9	$ 47.6	$ 48.2	$ 45.3	$ 46.1	$ 46.8	$ 47.5	$ 48.0
+ Depreciation	$ 11.2	$ 11.3	$ 11.4	$ 11.6	$ 11.7	$ 11.9	$ 11.2	$ 11.4	$ 11.6	$ 11.7	$ 11.9
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
- Change in Working Capital	$ -	$ 1.0	$ 1.2	$ 1.3	$ 1.3	$ 1.3	$ (6.6)	$ 1.8	$ 1.5	$ 1.5	$ 1.0
Cash Flows from Operations	$ 56.5	$ 56.1	$ 56.6	$ 57.3	$ 58.0	$ 58.7	$ 63.0	$ 55.7	$ 56.9	$ 57.8	$ 58.8
- Ordinary Capital Expenditures	$ 12.1	$ 12.2	$ 12.4	$ 12.5	$ 12.7	$ 12.9	$ 12.0	$ 12.3	$ 12.5	$ 12.6	$ 12.8
- Capital Conversion Costs	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 44.4**	**$ 43.8**	**$ 44.2**	**$ 44.7**	**$ 45.3**	**$ 45.9**	**$ 51.0**	**$ 43.4**	**$ 44.4**	**$ 45.1**	**$ 46.0**
Discounted Cash Flow											
Free Cash Flow	$ 44.4	$ 43.8	$ 44.2	$ 44.7	$ 45.3	$ 45.9	$ 51.0	$ 43.4	$ 44.4	$ 45.1	$ 46.0
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*0.000*	*0.931*	*0.867*	*0.807*	*0.752*	*0.700*	*0.652*	*0.607*	*0.565*	*0.526*
Discounted Cash Flow	**$ -**	**$ -**	**$ 41.2**	**$ 38.8**	**$ 36.6**	**$ 34.5**	**$ 35.7**	**$ 28.3**	**$ 26.9**	**$ 25.5**	**$ 24.2**
INPV at No STDs Case	**$ 585.7**										

Figure 12A.2.1 Detailed Income Statement and Cash Flow Statement Example

APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

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APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

13A.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2) and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. DOE's methodology is based on results published with the most recent edition of the *Annual Energy Outlook (AEO)* which is published by the Energy Information Agency (EIA). For this analysis DOE used *AEO 2022*.[1] DOE developed end-use specific emissions intensity coefficients, in units of mass of pollutant per kWh of site (grid) electricity, for each pollutant. The methodology is based on the more general approach used for all the utility sector impacts calculations, which is described in appendix 15A of this TSD and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin, 2019).[2,3] This appendix describes the methodology used to estimate the upstream emissions factors, and presents the values used for all emissions factors.

13A.2 POWER SECTOR AND SITE EMISSIONS FACTORS

Power sector marginal emissions factors are calculated by looking at the difference, over the full analysis period, in fuel consumption and emissions across a variety of cases published with the AEO. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of fuel used in (grid) electricity generation for each of the primary fossil fuel types (coal, natural gas and oil). These factors are combined with estimates of the fraction of generation allocated to each fuel type, also calculated from *AEO 2022* data, for each sector and end-use. The result is a set of end-use specific marginal emissions intensity factors, summarized in the tables below. Total emissions reductions are estimated by multiplying the intensity factors times the energy savings calculated in the national impact analysis (chapter 10). Power sector emissions factors are presented in Table 13A.4.2 through Table 13A.4.7.

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating or cooking applications) also produces emissions of CO_2 and other pollutants. To quantify the reduction in these emissions from a considered standard level, DOE used emissions intensity factors from Environmental Protection Agency (EPA) publications.[4] These factors, presented in Table 13A.4.1, are constant in time. The EPA defines SO_2 emissions in terms of a formula that depends on the sulfur content of the fuel. The typical use of petroleum-based fuels in buildings if for heating, and a typical sulfur content for heating oils is a few hundred parts-per-million (ppm). The value provided in Table 13A.4.1 corresponds to a sulfur content of approximately 100 ppm.

13A.3 UPSTREAM FACTORS

The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[5] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The FFC accounting approach is described briefly in appendix 10B and in Coughlin (2013).[5] When demand for a particular fuel is reduced, there is a corresponding reduction in the upstream activities associated with production of that fuel (mining, refining etc.) These upstream activities also consume energy and therefore produce combustion emissions. The FFC accounting estimates the total consumption of electricity, natural gas and petroleum-based fuels in these upstream activities. The relevant combustion emissions factors are then applied to this fuel use to determine the total upstream emissions intensities from combustion, per unit of fuel delivered to the consumer.

In addition to combustion emissions, extraction and processing of fossil fuels also produces fugitive emissions of CO_2 and CH_4. Fugitive emissions of CO_2 are small relative to combustion emissions, comprising about 2-3 percent of total CO_2 emissions for natural gas and 1-2 percent for petroleum fuels. In contrast, the fugitive emissions of methane from fossil fuel production are relatively large compared to combustion emissions of CH_4. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Fugitive emissions factors for CO_2 and methane from coal mining and natural gas production were estimated based on a review of recent studies compiled by Burnham (2011).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7,8] The value for methane, if it were translated to a leakage rate, would be equivalent to 1.3%. Actual leakage rates of methane at various stages of the production process are highly variable and the subject of ongoing research. In a comprehensive review of the literature, Brandt et al. (2014)[8] find that, while regional studies with very high emissions rates may not be representative of typical natural gas systems, it is also true that official inventories have most likely underestimated methane emissions. As more data are made available, DOE will continue to update these estimated emissions factors.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13A.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_X emissions do not apply to upstream combustion sources, so some components of the upstream fuel cycle (particularly off-road mobile engines) can contribute significantly to the upstream NO_x emissions factors.

13A.4 DATA TABLES

Summary tables of all the emissions factor data used by DOE for rules using *AEO 2022* are presented in the tables below. Table 13A.4.1 provides combustion emissions factors for fuels commonly used in buildings. Table 13A.4.2 to Table 13A.4.7 present the marginal power sector emissions factors as a function of sector and end use for a selected set of years. Table 13A.4.8 to Table 13A.4.10 provide the upstream emissions factors for all pollutants, for site electricity, natural gas and petroleum fuels. In all cases, the emissions factors are defined relative to the site electricity supplied from the grid and site use of the fuel.

Table 13A.4.1 Site Combustion Emissions Factors

Species	Natural Gas g/mcf	Distillate Oil g/bbl
CH_4	1.03E+00	1.33E+01
CO_2	5.47E+04	4.46E+05
N_2O	1.03E-01	8.65E+00
NO_x	4.36E+01	3.62E+02
SO_2	2.73E-01	2.20E+02

Table 13A.4.2 Power Sector Emissions Factors for CO_2 (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	477	417	369	341	324	313
Cooking	472	412	365	337	321	310
Freezers	486	424	376	347	330	318
Lighting	486	424	375	346	328	316
Refrigeration	485	424	376	347	329	318
Space Cooling	457	400	358	333	318	308
Space Heating	492	429	379	349	331	319
Water Heating	478	417	369	340	324	312
Other Uses	477	416	368	340	324	312
Commercial Sector						
Cooking	440	383	340	316	302	292
Lighting	449	391	347	322	307	297
Office Equipment (Non-Pc)	426	370	330	307	294	285
Office Equipment (Pc)	426	370	330	307	294	285
Refrigeration	473	412	365	337	321	310
Space Cooling	449	393	352	328	314	305
Space Heating	495	432	381	351	333	321
Ventilation	473	413	366	338	321	310
Water Heating	439	382	339	315	301	291
Other Uses	432	376	334	311	297	288
Industrial Sector						
All Uses	432	376	334	311	297	288

Table 13A.4.3 Power Sector Emissions Factors for CH_4 (Million Short Tons (MMst)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.0374	0.0328	0.0282	0.0250	0.0227	0.0214
Cooking	0.0365	0.0320	0.0276	0.0244	0.0222	0.0210
Freezers	0.0385	0.0338	0.0291	0.0258	0.0234	0.0221
Lighting	0.0389	0.0342	0.0294	0.0260	0.0236	0.0223
Refrigeration	0.0384	0.0337	0.0290	0.0257	0.0234	0.0221
Space Cooling	0.0330	0.0289	0.0249	0.0221	0.0201	0.0190
Space Heating	0.0398	0.0350	0.0301	0.0267	0.0242	0.0228
Water Heating	0.0377	0.0331	0.0284	0.0252	0.0229	0.0216
Other Uses	0.0373	0.0327	0.0282	0.0250	0.0227	0.0214
Commercial Sector						
Cooking	0.0317	0.0278	0.0239	0.0212	0.0193	0.0182
Lighting	0.0330	0.0289	0.0249	0.0221	0.0201	0.0190
Office Equipment (Non-Pc)	0.0294	0.0257	0.0221	0.0196	0.0179	0.0169
Office Equipment (Pc)	0.0294	0.0257	0.0221	0.0196	0.0179	0.0169
Refrigeration	0.0366	0.0322	0.0277	0.0245	0.0223	0.0210
Space Cooling	0.0317	0.0278	0.0239	0.0213	0.0193	0.0183
Space Heating	0.0403	0.0354	0.0305	0.0270	0.0245	0.0231
Ventilation	0.0368	0.0323	0.0278	0.0246	0.0224	0.0211
Water Heating	0.0316	0.0277	0.0238	0.0211	0.0192	0.0181
Other Uses	0.0304	0.0266	0.0229	0.0203	0.0185	0.0175
Industrial Sector						
All Uses	0.0304	0.0266	0.0229	0.0203	0.0185	0.0175

Table 13A.4.4 Power Sector Emissions Factors for Hg (Short Tons (sT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	1.207	1.067	0.994	0.955	0.886	0.939
Cooking	1.175	1.038	0.967	0.929	0.862	0.913
Freezers	1.249	1.104	1.029	0.989	0.918	0.973
Lighting	1.267	1.120	1.044	1.004	0.932	0.988
Refrigeration	1.246	1.101	1.026	0.987	0.916	0.970
Space Cooling	1.033	0.910	0.846	0.812	0.752	0.796
Space Heating	1.304	1.153	1.075	1.034	0.960	1.018
Water Heating	1.220	1.078	1.005	0.965	0.896	0.950
Other Uses	1.205	1.065	0.992	0.953	0.885	0.937
Commercial Sector						
Cooking	0.996	0.878	0.816	0.782	0.725	0.767
Lighting	1.045	0.922	0.857	0.822	0.762	0.807
Office Equipment (Non-Pc)	0.907	0.798	0.740	0.709	0.656	0.694
Office Equipment (Pc)	0.907	0.798	0.740	0.709	0.656	0.694
Refrigeration	1.181	1.043	0.971	0.933	0.866	0.917
Space Cooling	0.984	0.867	0.805	0.772	0.715	0.756
Space Heating	1.322	1.169	1.090	1.049	0.974	1.033
Ventilation	1.186	1.048	0.976	0.938	0.870	0.922
Water Heating	0.992	0.874	0.812	0.779	0.721	0.763
Other Uses	0.945	0.832	0.773	0.741	0.686	0.725
Industrial Sector						
All Uses	0.945	0.832	0.773	0.741	0.686	0.725

Table 13A.4.5 Power Sector Emissions Factors for N_2O (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.00528	0.00463	0.00398	0.00351	0.00317	0.00299
Cooking	0.00515	0.00452	0.00388	0.00343	0.00310	0.00292
Freezers	0.00544	0.00478	0.00410	0.00362	0.00327	0.00309
Lighting	0.00550	0.00484	0.00415	0.00366	0.00331	0.00312
Refrigeration	0.00543	0.00477	0.00410	0.00362	0.00327	0.00308
Space Cooling	0.00464	0.00406	0.00349	0.00308	0.00278	0.00263
Space Heating	0.00564	0.00496	0.00425	0.00376	0.00339	0.00320
Water Heating	0.00532	0.00467	0.00401	0.00354	0.00320	0.00301
Other Uses	0.00527	0.00463	0.00397	0.00350	0.00317	0.00298
Commercial Sector						
Cooking	0.00445	0.00390	0.00334	0.00295	0.00267	0.00251
Lighting	0.00464	0.00407	0.00349	0.00308	0.00278	0.00262
Office Equipment (Non-Pc)	0.00411	0.00359	0.00308	0.00272	0.00246	0.00232
Office Equipment (Pc)	0.00411	0.00359	0.00308	0.00272	0.00246	0.00232
Refrigeration	0.00517	0.00454	0.00390	0.00344	0.00311	0.00293
Space Cooling	0.00445	0.00390	0.00334	0.00296	0.00267	0.00252
Space Heating	0.00572	0.00502	0.00431	0.00381	0.00344	0.00324
Ventilation	0.00519	0.00456	0.00391	0.00345	0.00312	0.00294
Water Heating	0.00443	0.00388	0.00332	0.00294	0.00265	0.00250
Other Uses	0.00426	0.00372	0.00319	0.00282	0.00255	0.00240
Industrial Sector						
All Uses	0.00426	0.00372	0.00319	0.00282	0.00255	0.00240

Table 13A.4.6 Power Sector Emissions Factors for NO_x (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.186	0.221	0.186	0.167	0.139	0.136
Cooking	0.183	0.218	0.183	0.164	0.137	0.134
Freezers	0.190	0.227	0.190	0.171	0.142	0.139
Lighting	0.191	0.227	0.190	0.171	0.142	0.139
Refrigeration	0.190	0.226	0.190	0.170	0.142	0.139
Space Cooling	0.173	0.206	0.174	0.157	0.131	0.129
Space Heating	0.194	0.231	0.194	0.173	0.144	0.141
Water Heating	0.186	0.222	0.186	0.167	0.139	0.136
Other Uses	0.185	0.221	0.185	0.166	0.139	0.136
Commercial Sector						
Cooking	0.166	0.196	0.165	0.149	0.124	0.122
Lighting	0.170	0.202	0.170	0.153	0.128	0.126
Office Equipment (Non-Pc)	0.158	0.187	0.157	0.142	0.119	0.117
Office Equipment (Pc)	0.158	0.187	0.157	0.142	0.119	0.117
Refrigeration	0.183	0.218	0.183	0.164	0.137	0.134
Space Cooling	0.169	0.201	0.170	0.153	0.128	0.126
Space Heating	0.196	0.233	0.195	0.175	0.145	0.142
Ventilation	0.184	0.218	0.183	0.165	0.137	0.135
Water Heating	0.165	0.196	0.165	0.148	0.124	0.122
Other Uses	0.161	0.191	0.161	0.145	0.121	0.120
Industrial Sector						
All Uses	0.161	0.191	0.161	0.145	0.121	0.120

Table 13A.4.7 Power Sector Emissions Factors for SO_2 (Million Short Tons (MMsT)/Quad of Site Electricity Use)

	2025	2030	2035	2040	2045	2050
Residential Sector						
Clothes Dryers	0.269	0.217	0.169	0.147	0.135	0.137
Cooking	0.262	0.211	0.165	0.144	0.132	0.134
Freezers	0.278	0.224	0.175	0.153	0.140	0.142
Lighting	0.281	0.226	0.177	0.154	0.142	0.144
Refrigeration	0.278	0.224	0.175	0.152	0.140	0.142
Space Cooling	0.236	0.189	0.147	0.128	0.117	0.118
Space Heating	0.288	0.233	0.182	0.159	0.146	0.148
Water Heating	0.271	0.218	0.170	0.149	0.136	0.139
Other Uses	0.268	0.216	0.169	0.147	0.135	0.137
Commercial Sector						
Cooking	0.224	0.179	0.140	0.122	0.111	0.113
Lighting	0.234	0.188	0.147	0.128	0.117	0.118
Office Equipment (Non-Pc)	0.205	0.164	0.128	0.111	0.101	0.103
Office Equipment (Pc)	0.205	0.164	0.128	0.111	0.101	0.103
Refrigeration	0.263	0.212	0.165	0.144	0.132	0.134
Space Cooling	0.226	0.181	0.141	0.122	0.111	0.113
Space Heating	0.292	0.236	0.184	0.161	0.148	0.150
Ventilation	0.264	0.213	0.166	0.145	0.133	0.135
Water Heating	0.223	0.179	0.139	0.121	0.111	0.112
Other Uses	0.213	0.171	0.133	0.116	0.105	0.107
Industrial Sector						
All Uses	0.213	0.171	0.133	0.116	0.105	0.107

Table 13A.4.8 Electricity Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MWh	27.1	24.8	23.3	22.8	22.7	22.6
CH_4	g/MWh	2233.3	2072.0	1959.8	1937.3	1957.8	1955.2
Hg	g/MWh	5.4E-06	4.7E-06	3.9E-06	3.3E-06	2.9E-06	2.6E-06
N_2O	g/MWh	0.152	0.136	0.121	0.110	0.102	0.098
NO_x	g/MWh	363.0	334.7	317.0	311.7	312.1	312.3
SO_2	g/MWh	2.4	2.1	1.8	1.6	1.4	1.3

Table 13A.4.9 Natural Gas Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MMcf	7.1	7.1	7.2	7.2	7.1	7.2
CH_4	g/MMcf	691.1	692.9	694.2	694.2	692.8	693.7
Hg	g/MMcf	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
N_2O	g/MMcf	0.011	0.011	0.011	0.011	0.011	0.011
NO_x	g/MMcf	100.3	100.5	101.5	101.7	101.2	102.2
SO_2	g/MMcf	0.0	0.0	0.0	0.0	0.0	0.0

Table 13A.4.10 Petroleum Fuels Upstream Emission Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/bbl	69.7	69.8	70.3	71.6	71.8	72.1
CH_4	g/bbl	950.3	944.3	943.6	960.6	963.1	965.8
Hg	g/bbl	4.7E-06	4.7E-06	4.4E-06	4.1E-06	3.8E-06	3.7E-06
N_2O	g/bbl	0.582	0.587	0.596	0.605	0.604	0.605
NO_x	g/bbl	762.3	770.8	785.5	799.3	799.2	802.3
SO_2	g/bbl	13.8	13.9	14.0	14.2	14.2	14.2

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APPENDIX 14A. SOCIAL COST OF GREENHOUSE GAS VALUES, 2020-2070

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14A.1 VALUES FOR SOCIAL COST OF GREENHOUSE GASES

The values in this appendix are taken from the model input files supporting the "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis" published by EPA in December 2021.[1,a] These values are themselves based on the 2020-2050 values in "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide; Interim Estimates under Executive Order 13990", published by the Interagency Working Group on Social Cost of Greenhouse Gases in February 2021.[2] To derive values for 2051-2070, EPA extrapolated based on methods, assumptions, and parameters identical to the 2020-2050 estimates published by the Interagency Working Group. The values in the EPA files are in 2018$. DOE converted these to 2020$ using the GDP deflator.[b] Due to a lack of available SC-CO_2 estimates for emissions years beyond 2070, DOE did not monetize the climate benefits of GHG emissions reductions occurring after 2070.

Table 14A.1.1 Interim Social Cost of CO_2 Values Based on 2021 Interagency Update and 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of CO_2)*

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	14	51	76	151
2021	15	52	77	155
2022	15	53	79	158
2023	16	54	80	162
2024	16	55	81	165
2025	17	56	83	169
2026	17	57	84	172
2027	18	58	85	176
2028	18	59	87	179
2029	19	60	88	183
2030	19	62	89	186
2031	20	63	91	190
2032	20	64	92	194
2033	21	65	93	198
2034	22	66	95	201
2035	22	67	96	205
2036	23	68	97	209
2037	23	70	99	213

[a] Model files available at: www3.epa.gov/otaq/ld/EPA-CCEMS-PostProcessingTool-Project-FRM.zip (last accessed January 18, 2022).
[b] For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

Discount Rate and Statistics				
Emissions Year	5%, Average	3%, Average	2.5%, Average	3%, 95th
2038	24	71	100	217
2039	25	72	101	220
2040	25	73	103	224
2041	26	74	104	228
2042	26	75	105	231
2043	27	76	107	235
2044	28	78	108	238
2045	28	79	109	242
2046	29	80	111	245
2047	30	81	112	249
2048	30	82	113	252
2049	31	83	115	256
2050	32	84	116	259
2051	32	85	118	260
2052	33	86	119	261
2053	34	87	120	262
2054	34	88	121	263
2055	35	89	122	265
2056	35	90	123	267
2057	36	91	124	269
2058	37	92	125	271
2059	37	92	127	273
2060	38	93	128	275
2061	39	95	129	280
2062	40	96	131	285
2063	41	98	132	290
2064	42	99	134	295
2065	44	100	135	300
2066	45	102	137	305
2067	46	103	138	311
2068	47	105	140	316
2069	48	106	141	321
2070	49	108	143	326

* Values are rounded off to the nearest dollar.

Table 14A.1.2 Interim Social Cost of CH_4 Values from 2021 Interagency Update and Interagency Update, 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of CH_4)*

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	663	1,480	1,946	3,893
2021	691	1,527	2,002	4,021
2022	718	1,574	2,057	4,149
2023	745	1,620	2,112	4,277
2024	772	1,667	2,167	4,405
2025	799	1,714	2,223	4,533
2026	826	1,761	2,278	4,661
2027	853	1,807	2,333	4,789
2028	880	1,854	2,388	4,917
2029	908	1,901	2,444	5,045
2030	935	1,948	2,499	5,173
2031	969	2,003	2,563	5,326
2032	1,003	2,058	2,626	5,479
2033	1,038	2,113	2,690	5,632
2034	1,072	2,168	2,754	5,786
2035	1,106	2,224	2,817	5,939
2036	1,140	2,279	2,881	6,092
2037	1,175	2,334	2,945	6,245
2038	1,209	2,389	3,008	6,399
2039	1,243	2,444	3,072	6,552
2040	1,277	2,500	3,136	6,705
2041	1,315	2,555	3,199	6,849
2042	1,352	2,611	3,261	6,993
2043	1,389	2,667	3,324	7,138
2044	1,427	2,722	3,387	7,282
2045	1,464	2,778	3,450	7,426
2046	1,502	2,834	3,512	7,570
2047	1,539	2,890	3,575	7,714
2048	1,576	2,945	3,638	7,859
2049	1,614	3,001	3,701	8,003
2050	1,651	3,057	3,763	8,147
2051	1,680	3,096	3,807	8,193
2052	1,703	3,128	3,841	8,228
2053	1,726	3,159	3,874	8,263
2054	1,749	3,190	3,908	8,297
2055	1,772	3,221	3,942	8,332

Discount Rate and Statistics				
Emissions Year	5%, Average	3%, Average	2.5%, Average	3%, 95th
2056	1,797	3,256	3,979	8,373
2057	1,823	3,291	4,017	8,415
2058	1,848	3,326	4,055	8,456
2059	1,873	3,360	4,092	8,497
2060	1,899	3,395	4,130	8,539
2061	2,021	3,548	4,296	9,067
2062	2,143	3,702	4,462	9,594
2063	2,264	3,856	4,628	10,122
2064	2,386	4,009	4,794	10,650
2065	2,508	4,163	4,960	11,177
2066	2,632	4,325	5,141	11,758
2067	2,757	4,488	5,323	12,338
2068	2,881	4,651	5,504	12,919
2069	3,006	4,814	5,686	13,499
2070	3,130	4,976	5,867	14,079

* Values are rounded off to the nearest dollar.

Table 14A.1.3 Interim Social Cost of N_2O Values from 2021 Interagency Update and 2021 EPA Light-Duty Vehicle Regulatory Impact Analysis, 2020–2070 (converted to 2020$ per Metric Ton of N_2O)*

Discount Rate and Statistics				
Emissions Year	5%, Average	3%, Average	2.5%, Average	3%, 95th
2020	5,760	18,342	27,037	48,090
2021	5,961	18,777	27,592	49,293
2022	6,162	19,213	28,147	50,497
2023	6,363	19,649	28,702	51,700
2024	6,565	20,084	29,257	52,904
2025	6,766	20,520	29,811	54,108
2026	6,967	20,955	30,366	55,311
2027	7,168	21,391	30,921	56,515
2028	7,370	21,827	31,476	57,718
2029	7,571	22,262	32,031	58,922
2030	7,772	22,698	32,585	60,125
2031	8,019	23,188	33,195	61,480
2032	8,266	23,678	33,804	62,834
2033	8,513	24,168	34,413	64,189
2034	8,760	24,659	35,023	65,543
2035	9,007	25,149	35,632	66,898

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2036	9,253	25,639	36,241	68,252
2037	9,500	26,129	36,850	69,606
2038	9,747	26,619	37,460	70,961
2039	9,994	27,110	38,069	72,315
2040	10,241	27,600	38,678	73,670
2041	10,530	28,127	39,320	75,089
2042	10,819	28,655	39,962	76,508
2043	11,109	29,183	40,604	77,928
2044	11,398	29,710	41,246	79,347
2045	11,687	30,238	41,888	80,766
2046	11,976	30,765	42,530	82,186
2047	12,265	31,293	43,172	83,605
2048	12,555	31,820	43,814	85,024
2049	12,844	32,348	44,456	86,443
2050	13,133	32,875	45,098	87,863
2051	13,479	33,426	45,727	88,606
2052	13,798	33,954	46,354	89,984
2053	14,118	34,483	46,981	91,362
2054	14,438	35,011	47,609	92,739
2055	14,758	35,539	48,236	94,117
2056	15,091	36,092	48,890	95,463
2057	15,425	36,644	49,544	96,808
2058	15,758	37,196	50,199	98,154
2059	16,091	37,748	50,853	99,499
2060	16,424	38,300	51,507	100,845
2061	17,077	39,165	52,485	103,794
2062	17,730	40,030	53,463	106,743
2063	18,382	40,895	54,441	109,692
2064	19,035	41,760	55,419	112,641
2065	19,687	42,625	56,397	115,590
2066	20,354	43,515	57,403	118,657
2067	21,020	44,404	58,409	121,725
2068	21,686	45,293	59,416	124,793
2069	22,352	46,183	60,422	127,860
2070	23,018	47,072	61,428	130,928

* Values are rounded off to the nearest dollar.

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APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X AND SO_2 EMISSIONS FROM ELECTRICITY GENERATION

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APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X AND SO_2 EMISSIONS FROM ELECTRICITY GENERATION

14B.1 INTRODUCTION

This appendix describes the analytical methodology DOE uses to incorporate regional and end use sector variability in NO_X and SO_2 valuations into the emissions monetization. The regional values assigned to these emissions are based on benefit-per-ton estimates published by EPA for a variety of sectors, including electricity generation. EPA provides high and low estimates of benefit-per-ton of NO_X and SO_2 emissions reductions in forty regions of the continental USA. DOE combined these data with regional information on electricity consumption and emissions to define weighted-average national values for NO_X and SO_2 as a function of sector.

DOE's methodology uses results associated with the most recent edition of the *Annual Energy Outlook (AEO)* published by the Energy Information Agency (EIA). For this analysis DOE used the Reference case from *AEO2022*.[1] The *AEO* data are used to define two sets of factors that enter into the calculation: the distribution of sectoral electricity consumption by region, and the magnitude of NO_X and SO_2 emissions in each region.

14B.2 METHODOLOGY

14B.2.1 EPA Data

In 2022 EPA published an updated Technical Support Document (TSD) describing an approach for estimating the average avoided human health impacts and monetized benefits related to emissions of $PM_{2.5}$ and ozone precursors including NO_X and SO_2 from 21 sectors.[a] The EPA TSD includes estimates of the present value of the benefits of NO_X and SO_2 emissions reductions (*benefit-per-ton* estimates or BPT) for 2025, 2030, 2035 and 2040. For NO_X, EPA provides values for $PM_{2.5}$ –related benefits and for ozone-related benefits. Because the pollutants associated with NO_X as $PM_{2.5}$ and SO_2 emissions persist in the atmosphere over a period of years, reductions in any given year will have benefits in subsequent years. These future benefits are discounted and summed to provide a single value for the reduction of one ton of emissions in the emissions year.

For Electricity generating units, EPA estimated a benefit per-ton for each of the 48 contiguous continental states. Some states are aggregated into larger regions (CT-RI, DE-NJ, ID-OR-WA, ME-MA-NH-VT, and ND-SD), resulting in separate BPT estimates for forty regions. BPT values for NO_x and SO_2 as precursors to $PM_{2.5}$ include high and low impact scenarios; BPT

[a] U.S. Environmental Protection Agency. *Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors*. January 2022. https://www.epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf

values for NOx as a precursor to ozone include short and long-term impacts. For all data two rates of discounting (3% and 7%) are provided.

DOE used linear interpolation to define values for the years between 2025 and 2030, 2030 and 2035, and 2035 and 2040; for years beyond 2040 the value is held constant. DOE defined the total value of NO_x emissions reductions as the sum of the BPT value for $PM_{2.5}$ plus one half of the BPT value for ozone; the factor of one-half accounts for the fact that ozone is primarily produced during the May-September period, so approximately half of NO_x emissions will produce ozone emissions.

14B.2.2 AEO Data

For this calculation DOE used the total annual emissions of NO_x and SO_2 for each of the *AEO*'s 25 Electricity Market Module (EMM) regions,[2] and data tables published with the NEMS code package.[b] The latter are used to map EPA regions to EMM regions, and to calculate the contribution of each utility customer sector (residential, commercial and industrial) to total pollutant emissions in each EMM region. The data are then combined to create time series of BPT values for each end use sector.

14B.2.3 Equations and Results

Consistent with its treatment of other utility and environmental impacts, DOE defines a times series of national average estimates of NO_x and SO_2 values.

The same methodology is applied to each pollutant type and EPA scenario (low-7%, low-3%, etc.). The notation is:

- y is the analysis year,
- m is a label for the EMM region,
- z is a label for the EOA region,
- w(z,m) is a matrix that maps EPA regions to EMM regions; it is defined as the fraction of total electricity sales within m to region z; $\sum_z w(z,m) = 1$ for all m,
- p(z,y) is the BPT estimate in EPA region z and year y,
- s is a label for the customer sector (commercial, residential, industrial)
- v(s, m) is the weight of sector s in EMM region m, defined as the fraction of total electricity sales within m to sector s; $\sum_s v(s,m) = 1$ for all m,

[b] The NEMS package can be downloaded at https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Once installed, the file path to the data files is aeo2021\reference\input\emm_db.zip. The data files are EMMCNTL_RDB.xlsx and LDSMSTR_RDB.xlsx.

- M(m,y) is total pollutant emissions in EMM region m and year y.

The calculation proceeds in four steps:

1. Pollutant emissions are allocated to sector:

$$M1(m, s, y) = M(m, y) * v(s, m)$$

2. Sectoral pollutant emissions are mapped from EMM regions to EPA regions:

$$M2(z, s, y) = \sum_m M1(m, s, y) * w(z, m)$$

3. A weight is defined for EPA region z and sector s, based on pollutant emissions:

$$u(z, s, y) = M2(z, s, y)/[\sum_z M2(z, s, y)]$$

4. The regional weights are used to define a national average BPT value for each sector:

$$P(s, y) = \sum z\ u(z, s, y) * p(z, y)$$

The results of this calculation are provided in Table 14B.3.1 for NO_x and in Table 14B.3.2 for SO_2. DOE's prices are not significantly different than the EPA estimate of the US average. Although the EPA prices are held constant after 2040, the DOE prices may vary slightly in the period 2040-2050 due to the projected changes in regional emissions.

Table 14B.3.1 NO_x Benefit-per-ton Values by Sector (2016$/ Short Ton)

Sector	High, 3% Discount Rate				High, 7% Discount Rate			
	2025	2030	2040	2050	2025	2030	2040	2050
Commercial	59,241	66,019	82,131	82,876	53,063	59,110	73,642	74,313
Industrial	58,828	65,753	80,552	81,237	52,694	58,888	72,242	72,859
Residential	59,102	65,922	81,783	82,420	52,939	59,018	73,327	73,901
Sector	**Low, 3% Discount Rate**				**Low, 7% Discount Rate**			
	2025	**2030**	**2040**	**2050**	**2025**	**2030**	**2040**	**2050**
Commercial	59,116	65,718	81,447	82,181	52,955	58,840	73,030	73,691
Industrial	58,685	65,389	79,743	80,418	52,572	58,561	71,522	72,129
Residential	58,985	65,632	81,129	81,756	52,839	58,758	72,743	73,308

Table 14B.3.2 SO_2 Benefit-per-ton Values by Sector (2016$/ Short Ton)

Sector	High, 3% Discount Rate				High, 7% Discount Rate			
	2025	**2030**	**2040**	**2050**	**2050**	**2030**	**2040**	**2050**
Commercial	81,598	92,092	115,167	116,405	73,416	82,827	103,617	104,725
Industrial	81,144	91,307	113,106	114,293	73,001	82,120	101,782	102,844
Residential	81,160	91,610	114,227	115,430	73,023	82,398	102,776	103,852
Sector	**Low, 3% Discount Rate**				**Low, 7% Discount Rate**			
	2025	**2030**	**2040**	**2050**	**2025**	**2030**	**2040**	**2050**
Commercial	80,231	88,263	106,241	107,326	72,148	79,360	95,597	96,573
Industrial	79,821	87,548	104,421	105,453	71,775	78,712	93,950	94,878
Residential	79,820	87,850	105,429	106,477	71,780	78,983	94,859	95,802

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APPENDIX 15A. UTILITY IMPACT ANALYSIS METHODOLOGY

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APPENDIX 15A. UTILITY IMPACT ANALYSIS METHODOLOGY

15A.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and power generation that result for each trial standard level (TSL). These changes are estimated by multiplying the site savings of electricity by a set of *impact factors* which measure the corresponding change in generation by fuel type, installed capacity, and power sector emissions. This Appendix describes the methods that DOE used to calculate these impact factors. The methodology is more fully described in Coughlin (2014; 2019).[1,2]

DOE's analysis uses output of the DOE/Energy Information Administration (EIA)'s most recent *Annual Energy Outlook* (*AEO*).[3] The *AEO* includes a reference case and a set of side cases that implement a variety of economic and policy scenarios. In 2015 EIA announced the adoption of a two-year release cycle for the *AEO*, alternating between a full set of scenarios and a shorter edition containing only five scenarios. DOE has adapted its calculation methodology to be independent of the type of scenarios available with each *AEO* publication.

15A.2 METHODOLOGY

Marginal reductions in electricity demand lead to marginal reductions in power sector generation, emissions, and installed capacity. Generally, DOE quantifies these reductions using marginal impact factors, which are time series defining the change in some power sector quantity that results from a unit change in site electricity demand. Because load shapes affect the mix of generation types on the margin, these impact factors depend on end-use and sector.

DOE's approach examines a series of *AEO* side cases to estimate the relationship between changes to power sector generation (TWh) by fuel type and changes to other supply-side power sector variables, including fuel consumption (quads) by fuel type, and installed capacity (GW) by fuel and technology type. DOE also calculates changes to power sector emissions; the methodology for computing these impacts is described in appendix 13A.

DOE uses load shape information from the NEMS code to relate marginal generation reductions by fuel type to marginal demand reductions by sector and end use. Because AEO side cases with electricity demand reductions are not always available, DOE defines the relationship between sector/end-use and generation fuel type using Reference case data. Specifically, DOE defines, for each sector and end-use, fuel-share weights equal to the percentage of each MWh used to serve that end-use load that is provided by each generation fuel type.

The load shape data provide an hourly profile defining total consumption of electricity for each sector/end-use. For each load DOE allocates consumption to one of 3 periods: on-peak, shoulder, and off-peak. These categories are used in the utility sector to correlate end-use consumption with supply types. On-peak hours are defined as 12pm to 5pm Monday through Saturday, June through September. Off-peak hours are 9pm to 6am daily and all day Sunday. All other hours are allocated to the shoulder period. This leads to a set of weights $w(p,u,y)$ where:

y = the analysis year
u = an index representing the sector/end-use (e.g. commercial cooling)
p = the time-of-day period
$w(p,u,y)$ = the fraction of load u that is served in period p

By definition the sum of $w(p,u,y)$ over periods p is equal to one. On the supply-side, DOE allocates generation by each fuel type to one of the time-of-day periods. The allocation is based on the following rules:

1.1. The data are normalized so that total annual generation equals total annual consumption by sector and end-use;

1.2. The demand-side data are summed over sector/end-use to define a total demand for generation in each time-of-day period;

1.3. All petroleum-based generation is allocated to peak periods;

1.4. Base-load generation (nuclear and coal) is assumed to be equally likely to be on in all hours; hence, it is allocated to each period in proportion to the number of hours in that period;

1.5. Any unmet peak period demand is allocated to natural gas;

1.6. The remaining generation of all types is allocated to the remaining periods proportionally.

This leads to a second set of weights $z(p,f,y)$ where:

f = the fuel type
$z(p,f,y)$ = the fraction of load in period p that is served by fuel f

These weights are used to allocate a MWh of demand reduction for a given end-use to each fuel type. In defining the fuel-share weights for demand reductions, DOE makes one adjustment to the factors calculated from the Reference case data. An examination of all available *AEO* scenarios shows that both generation and installed capacity for nuclear power are unchanged across the projection period. This implies that the use of nuclear power is not affected by small changes in the supply/demand balance; hence, DOE assumes that the factor $z(p,f,y)$ is zero for nuclear power. The values of $z(p,f,y)$ for the other fuels are renormalized so that the sum of $z(p,f,y)$ across the remaining fuel types is equal to one.

DOE defines the generation fuel share weights $g(u,f,y)$ as the product

$$g(u,f,y) = \sum_p w(p,u,y)\, z(p,f,y).$$

Eq. 15A.1

For the sector/end-use defined by u, the product of the total annual site electricity savings times the factor $g(u,f,y)$ defines the marginal generation reductions by fuel type. These marginal generation reductions can be related to marginal fuel use reductions (see appendix 10.B of this TSD) and to the marginal emissions reductions (see appendix 13A of this TSD). They are also related to the marginal installed capacity reductions through the capacity factor.

DOE uses a capacity factor to relate reductions in generation by fuel type to reductions in installed capacity by technology type. The capacity factor is defined as the magnitude of change in capacity given a unit change in generation. The technology types are coal, natural gas combined-cycle (NGCC), oil and gas steam (OGS), combustion turbine-diesel (CTD), and renewable sources. For NGCC the capacity factor is defined as the ratio of NGCC capacity to natural gas generation. DOE combines CTD and OGS DOE into a single *peak* capacity type, with capacity factor equal to the ratio of the sum of CTD plus OGS capacity to oil-fired generation. Each fuel type is then related to a unique capacity type. While marginal capacity factors can be calculated from *AEO* data, this approach produces results that are dominated by computational noise. Hence, DOE uses data for the *AEO Reference Case* to calculate grid-average capacity factors for each year of the analysis period, defined as $c(f,y)$. The capacity change for fuel/technology type f induced by a unit reduction in demand for sector/end-use u is given by the product $g(u,f,y)*c(f,y)$.

15A.3 MODEL RESULTS

Representative values of the impact factors for fuel share by fuel type, and capacity by technology type are provided in the tables below. The tables show the factors for two years, 2025 and 2050. The marginal heat rates are presented in appendix 10B and emissions factors are presented in in appendix 13A.

15A.3.1 Electricity Generation

Table 15A.3.1 and Table 15A.3.2 show the distribution across fuel types of a unit reduction in electricity demand by sector and end-use, referred to above as fuel-share weights. The fuel types are coal, natural gas, petroleum, and renewables. The values for cooling are representative of peaking loads, while the values for refrigeration are representative of flat loads. The data are shown for 2025 and 2050.

Table 15A.3.1 Fuel-Share Weights by Sector and End-Use (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	25.3%	38.9%	0.2%	35.6%
Cooking	24.6%	39.3%	0.2%	35.9%
Freezers	26.2%	38.5%	0.2%	35.1%
Lighting	26.6%	37.9%	0.1%	35.5%
Refrigeration	26.1%	38.5%	0.2%	35.2%
Space Cooling	21.7%	42.4%	0.6%	35.3%
Space Heating	27.3%	37.3%	0.0%	35.4%
Water Heating	25.6%	38.5%	0.1%	35.8%
Other Uses	25.3%	38.9%	0.2%	35.7%
Commercial Sector				
Cooking	20.9%	41.6%	0.3%	37.3%
Lighting	21.9%	41.0%	0.3%	36.9%
Office Equipment (Non-Pc)	19.0%	42.9%	0.4%	37.7%
Office Equipment (Pc)	19.0%	42.9%	0.4%	37.7%
Refrigeration	24.8%	39.2%	0.2%	35.9%
Space Cooling	20.6%	43.1%	0.7%	35.5%
Space Heating	27.7%	37.1%	0.0%	35.2%
Ventilation	24.9%	39.1%	0.2%	35.9%
Water Heating	20.8%	41.6%	0.3%	37.4%
Other Uses	19.8%	42.3%	0.3%	37.5%
Industrial Sector				
All Uses	19.8%	42.3%	0.3%	37.5%

Table 15A.3.2 Fuel-Share Weights by Sector and End-Use (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	14.1%	36.2%	0.1%	49.6%
Cooking	13.7%	36.5%	0.1%	49.7%
Freezers	14.6%	36.1%	0.1%	49.2%
Lighting	14.8%	35.1%	0.0%	50.0%
Refrigeration	14.6%	36.1%	0.1%	49.3%
Space Cooling	11.9%	40.5%	0.2%	47.3%
Space Heating	15.3%	34.6%	0.0%	50.2%
Water Heating	14.2%	35.7%	0.0%	50.1%
Other Uses	14.1%	36.2%	0.1%	49.7%
Commercial Sector				
Cooking	11.5%	38.1%	0.1%	50.3%
Lighting	12.1%	37.7%	0.1%	50.1%
Office Equipment (Non-Pc)	10.4%	39.3%	0.1%	50.1%
Office Equipment (Pc)	10.4%	39.3%	0.1%	50.1%
Refrigeration	13.8%	36.4%	0.1%	49.8%
Space Cooling	11.3%	41.2%	0.3%	47.3%
Space Heating	15.5%	34.4%	0.0%	50.1%
Ventilation	13.8%	36.3%	0.1%	49.8%
Water Heating	11.4%	38.0%	0.1%	50.4%
Other Uses	10.9%	38.8%	0.1%	50.2%
Industrial Sector				
All Uses	10.9%	38.8%	0.1%	50.2%

15A.3.2 Installed Capacity

Table 15A.3.3 and Table 15A.3.4 show the total change in installed capacity (GW) per unit of site electricity demand reduction for the five principal capacity types: coal, natural gas, peaking, renewables, and nuclear. The peaking category is the sum of the two NEMS categories oil and gas steam and combustion turbine/diesel. Data are shown for 2025 and 2050.

Table 15A.3.3 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.061	0.097	0.046	0.134
Cooking	0.060	0.098	0.052	0.135
Freezers	0.063	0.096	0.050	0.132
Lighting	0.064	0.095	0.017	0.133
Refrigeration	0.063	0.096	0.049	0.132
Space Cooling	0.052	0.106	0.174	0.133
Space Heating	0.066	0.093	0.002	0.133
Water Heating	0.062	0.096	0.028	0.135
Other Uses	0.061	0.097	0.043	0.134
Commercial Sector				
Cooking	0.051	0.104	0.078	0.140
Lighting	0.053	0.103	0.072	0.139
Office Equipment (Non-Pc)	0.046	0.107	0.106	0.142
Office Equipment (Pc)	0.046	0.107	0.106	0.142
Refrigeration	0.060	0.098	0.047	0.135
Space Cooling	0.050	0.108	0.188	0.134
Space Heating	0.067	0.093	0.000	0.132
Ventilation	0.060	0.098	0.045	0.135
Water Heating	0.050	0.104	0.074	0.140
Other Uses	0.048	0.106	0.095	0.141
Industrial Sector				
All Uses	0.048	0.106	0.095	0.141

Table 15A.3.4 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.031	0.111	0.052	0.187
Cooking	0.030	0.112	0.059	0.187
Freezers	0.032	0.110	0.057	0.185
Lighting	0.032	0.107	0.019	0.188
Refrigeration	0.032	0.110	0.056	0.185
Space Cooling	0.026	0.124	0.197	0.178
Space Heating	0.033	0.106	0.002	0.189
Water Heating	0.031	0.109	0.032	0.188
Other Uses	0.031	0.111	0.049	0.187
Commercial Sector				
Cooking	0.025	0.117	0.088	0.189
Lighting	0.027	0.115	0.082	0.188
Office Equipment (Non-Pc)	0.023	0.120	0.120	0.189
Office Equipment (Pc)	0.023	0.120	0.120	0.189
Refrigeration	0.030	0.111	0.054	0.187
Space Cooling	0.025	0.126	0.214	0.178
Space Heating	0.034	0.105	0.000	0.189
Ventilation	0.030	0.111	0.051	0.188
Water Heating	0.025	0.116	0.084	0.190
Other Uses	0.024	0.119	0.108	0.189
Industrial Sector				
All Uses	0.024	0.119	0.108	0.189

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- Projections of annual market share increases for the alternative policies;
- NIA-RIA Integrated Model;
- Market penetration curves used to analyze consumer rebates and voluntary energy efficiency targets, including:
    - Background material on XENERGY's approach,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used to derive interpolated, customized curves;
- Detailed table of rebates offered for the considered product, as well as DOE's approach to estimate a market representative rebate value for this RIA; and
- Background material on Federal and State tax credits for appliances.

17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17A.2.1 and Table 17A.2.2 show the annual increases in market shares of electric pool heaters and gas pool heaters, respectively, that meet the target efficiency levels for the selected TSL (TSL 5). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Electric Pool Heaters (TSL 5)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2028	37.2%	22.3%	11.1%	6.2%
2029	37.2%	22.3%	11.2%	8.7%
2030	37.2%	22.3%	11.2%	11.1%
2031	37.2%	22.3%	11.2%	13.4%
2032	37.2%	22.3%	11.2%	15.6%
2033	37.2%	22.3%	11.2%	17.6%
2034	37.2%	22.3%	11.2%	19.5%
2035	37.2%	22.3%	11.2%	21.2%
2036	37.2%	22.3%	11.2%	22.9%
2037	37.2%	22.3%	11.2%	24.5%
2038	37.2%	22.3%	11.2%	24.5%
2039	37.2%	22.3%	11.2%	24.5%
2040	37.2%	22.3%	11.2%	24.5%
2041	37.2%	22.3%	11.2%	24.5%
2042	37.2%	22.3%	11.2%	24.4%
2043	37.2%	22.3%	11.1%	24.4%
2044	37.2%	22.3%	11.1%	24.4%
2045	37.2%	22.3%	11.1%	24.4%
2046	37.2%	22.3%	11.1%	24.3%
2047	37.1%	22.3%	11.1%	24.3%
2048	37.1%	22.3%	11.1%	24.3%
2049	37.1%	22.3%	11.1%	24.2%
2050	37.1%	22.3%	11.1%	24.2%
2051	37.1%	22.3%	11.1%	24.2%
2052	37.1%	22.3%	11.1%	24.2%
2053	37.1%	22.3%	11.1%	24.1%
2054	37.1%	22.3%	11.1%	24.1%
2055	37.1%	22.3%	11.1%	24.1%
2056	37.1%	22.3%	11.1%	24.1%
2057	37.1%	22.3%	11.1%	24.1%

Table 17A.2.2 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Gas Pool Heaters (TSL 5)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets
2028	33.7%	20.2%	10.1%	0.7%
2029	33.5%	20.1%	10.1%	1.8%
2030	33.4%	20.0%	10.0%	2.7%
2031	33.2%	19.9%	10.0%	3.6%
2032	33.2%	19.9%	10.0%	4.4%
2033	33.1%	19.9%	9.9%	5.2%
2034	33.1%	19.9%	9.9%	5.9%
2035	33.1%	19.8%	9.9%	6.6%
2036	33.0%	19.8%	9.9%	7.3%
2037	33.0%	19.8%	9.9%	8.0%
2038	32.9%	19.8%	9.9%	8.0%
2039	32.9%	19.7%	9.9%	8.1%
2040	32.9%	19.7%	9.9%	8.1%
2041	32.9%	19.7%	9.9%	8.2%
2042	32.8%	19.7%	9.9%	8.2%
2043	32.8%	19.7%	9.9%	8.3%
2044	32.8%	19.7%	9.8%	8.3%
2045	32.8%	19.7%	9.8%	8.3%
2046	32.8%	19.7%	9.8%	8.4%
2047	32.8%	19.7%	9.8%	8.4%
2048	32.8%	19.7%	9.8%	8.4%
2049	32.7%	19.6%	9.8%	8.4%
2050	32.7%	19.6%	9.8%	8.4%
2051	32.7%	19.6%	9.8%	8.5%
2052	32.7%	19.6%	9.8%	8.5%
2053	32.7%	19.6%	9.8%	8.5%
2054	32.7%	19.6%	9.8%	8.5%
2055	32.7%	19.6%	9.8%	8.5%
2056	32.7%	19.6%	9.8%	8.6%
2057	32.7%	19.6%	9.8%	8.6%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that the Department built on the NIA model discussed in chapter 10 and documented in appendix 10A. The resulting integrated NIA-RIA model features both the NIA and RIA inputs, analyses and results. It has the capability to generate results, by product class and TSL, for the mandatory standards and each of the RIA policies. Separate modules estimate increases in market penetration of more efficient equipment for consumer rebates and voluntary energy efficiency targets.[b] The consumer rebates module calculates benefit-cost (B/C) ratios and market barriers, and generates customized market penetration curves for each product class; and the voluntary energy efficiency targets module relies on the market barriers calculated in the consumer rebates module to project a reduction in those barriers over the first ten years of the forecast period and estimate the market effects of such a reduction. A separate module summarizes the market impacts from mandatory standards, calculated under the same market conditions as the alternative polices, and all policy alternatives. An additional module produces all tables and figures presented in chapter 17 as well as the tables of market share increases for each policy reported in Section 17A.2 of this appendix.

17A.4 MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates and Voluntary Energy Efficiency Targets policies. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop interpolated penetration curves for pool heaters that meet the target efficiency levels at each TSL. The resulting curves for the selected TSL are presented in chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[c], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able to conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

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[a] NIA = National Impact Analysis; RIA = Regulatory Impact Analysis
[b] As mentioned in chapter 17, the increase in market penetrations for consumer tax credits and manufacturer tax credits are estimated as a fraction of the increase in market penetration of consumer rebates.
[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial advertising). The model incorporates both internal and external sources by combining a logistic function with an exponential function.[4, 5]

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[4,5,5] If adoption of a product is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs at the beginning of the process. In this scenario, external sources provide immediate information exposure to a significant number of prospective adopters. In contrast, internal sources (such as a network of prospective adopters) are relatively small in size and reach, producing a more gradual exposure to prospective adopters. Graphically speaking, information diffusion dominated by external sources is represented by a concave curve (the exponential curve in Figure 17A.4.1). If adoption of a new product is influenced most strongly by internal sources of information, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17A.4.1).

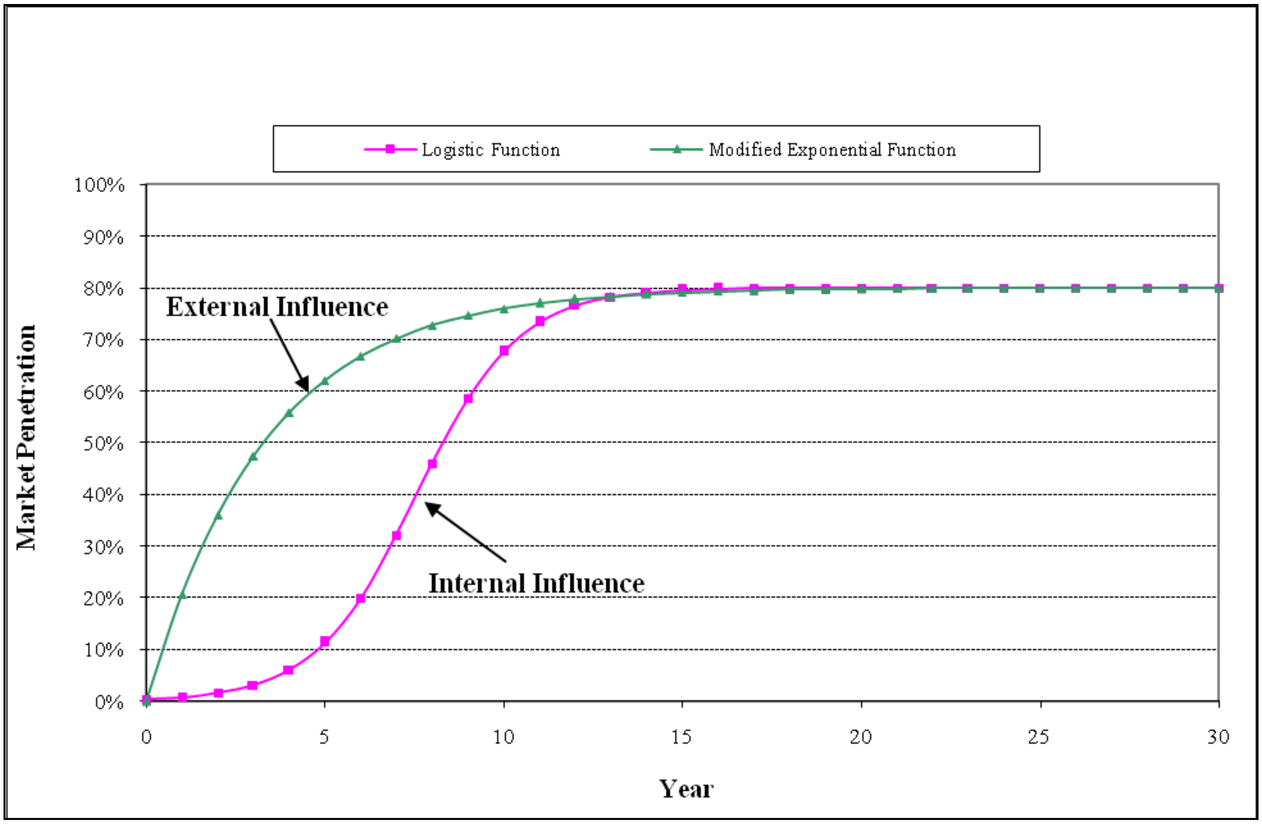

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17A.4.2 Adjustment of XENERGY Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study who later conducted similar California studies, DOE made some adjustments to XENERGY's original implementation (penetration) curves.[6, 7] The experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels:

Moderate Barriers:	70%
High Barriers:	60%
Extremely High Barriers:	50%

The *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves (discussed below), DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds, respectively, for any benefit/cost ratio points higher or lower than the curves. It set another constraint such that the policy case market share cannot be great than 100 percent, as might occur for products with high no-new-standards case market shares of the target-level technology.

17A.4.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[d] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[e] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

Blum et al (2011, appendix A)[8] presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The referred report describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

DOE used the above referred method to interpolate market implementation curves, to generate customized curves that were used to estimate the effects of consumer rebates and voluntary energy efficiency targets for each product class covered by this RIA. For consumer rebates, DOE derived such curves based on an algorithm that finds the market implementation curve that best fits, for the first year of the analysis period, the B/C ratio of the target efficiency level and the market penetration of equipment with that level of energy efficiency in the no-new-standards case. For the analysis of voluntary energy efficiency targets, DOE departs from the market barriers level corresponding to the market implementation curve it derived for consumer rebates, to linearly decrease it over the ten initial years of the analysis period. For each year, as market barriers decline, the corresponding market implementation curve leads – for the same B/C ratio – to higher market penetrations.

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[d] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[e] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets are considered in this RIA proportional to the impacts from rebates.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed an internet search for rebate programs that offered incentives for pool heaters in June, 2021. DOE found a total of 11 rebates related to pool heaters. Of those, 5 are related to the energy source (*i.e., natural gas, solar energy)* rather than to increasing the efficiency of the product. Table 17A.5.1 provides the organizations' name, state, rebate amount, and program website (as it was available at the time DOE performed the search) for the 6 remaining rebates that are relevant to this analysis. DOE analyzed the three rebate programs available for electric pool heaters listed in Table 17A.5.1 to estimate a representative rebate value for this product. The first rebate is offered for pool heaters with a coefficient of performance (COP) lower than 6, which is lower than the efficiency set for the selected standard level. Therefore, DOE used the average of the second and third rebates (bolded) listed in Table 17A.5.1, $700.00, as a representative rebate value for electric pool heaters. For gas pool heaters, DOE analyzed the three rebates listed in Table 17A.5.1 that are offered for this product. The first gas rebate shown in the table is offered for gas pool heaters with a thermal efficiency (TE) equal to or greater than 90%, which is significantly higher than the TE of the selected standard level. Therefore, DOE used the average of the last two rebates shown in the table (bolded), $575.00, as a representative rebate value for gas pool heaters, although they are both offered for gas pool heaters with a TE of at least 84%.

Table 17A.5.1 Rebates Programs for Pool Heaters[f]

Organization	State	Rebate*	Website
Electric Pool Heater Rebates			
CenterPoint Energy	IN	$500	https://midwest.centerpointenergy.com/savings/in-home/rebates/water-heating
CenterPoint Energy	**IN**	**$1,000**	https://midwest.centerpointenergy.com/savings/in-home/rebates/water-heating
Dakota Electric Association	**MN**	**$400**	https://www.dakotaelectric.com/member-services/programs-rebates/for-your-home/energy-wise-rebates/
Gas Pool Heater Rebates			
SoCalGas	CA	$750	https://www.socalgas.com/rebate-app
SoCalGas	**CA**	**$400**	https://www.socalgas.com/rebate-app
SoCalGas	**CA**	**$750****	https://www.socalgas.com/for-your-business/energy-savings/rebates-for-property-managers-owners

*In 2021$.
**Based on the $3/kBtu rebate offered and a representative capacity of 250 kBtu estimated for gas pool heaters.

[f] This table is based on rebate programs DOE found to be available through an extensive internet search during June, 2021. The programs referenced—and consequently their websites—may no longer be available by the time this document is published. To view the webpage hyperlinked in this table, copy the website address into a web browser's address window (rather than simply clicking on the hyperlinked text).

17A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

17A.1.1 Federal Tax Credits for Consumers

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas, oil and propane furnaces and boilers; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[9] These tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by the American Recovery and Reinvestment Act (ARRA).[10] There was a $1,500 cap on the credit per home, including the amount received for insulation, windows, and air and duct sealing. Congress extended this provision for 2011, with some modifications to eligibility requirements, and reductions in the cap to $500 per home. The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[11]
The tax credit for furnace fans was $50 in 2011, after which it expired.

The importance of the Federal tax credits has been emphasized in research in the residential heating industry on the impacts of the relatively large credits that were available for HVAC (heating, ventilating, and air conditioning) equipment. In a survey of HVAC distributors conducted by Vermont Energy Investment Corporation, respondents indicated that the ample credit had had a notable impact on sales of higher-efficiency heating and cooling equipment. Some distributors combined the Federal tax credits with manufacturer rebates and utility program rebates for a greater consumer incentive. However, when the amount of the Federal tax credit was reduced, smaller utility rebate incentives had not induced the same levels of equipment sales increases. The decrease in incentive size from a $1,500 cap in 2009-2010 to a $500 cap in 2011, during a period when the economy continued to be sluggish, resulted in a decline in total sales of residential HVAC products. Distributors stated that an incentive needed to cover 25 to 75 percent of the incremental cost of the efficient equipment to influence consumer choice. The industry publication "2011 HVAC Review and Outlook" noted a decline in sales of air conditioning units with >14 SEER in 2011 and a return in sales of units with >16 SEER to 2009 levels (after an increase in 2010). The large majority of distributors observed no impacts from the utility programs with their lower rebate amounts available in 2011. Distributors also commented on the advantages of the Federal tax credit being nationwide in contrast to utility rebate programs that target regional markets.[12, 13]

In an effort to evaluate the potential impact of a Federal appliance tax credit program, DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. It estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[14] It also estimated the percentage of taxpayers with entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. DOE reasoned that the percentage of taxpayers with an entry on Line 3b could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for furnaces during the initial program years. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007, claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for any qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[15], [16], [17] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to each product class of pool heaters covered by this RIA. Hence it was difficult to compare these detailed estimates to the more general data analysis described above from the existing Federal tax credit program, or to use the IRS data analysis in its consumer tax credit analysis.

17A.6.1 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[18] The Emergency Economic Stabilization Act of 2008[19] amended the credits and extended them through 2010. The credits were extended again to 2011 with modifications in the eligibility requirements. Manufacturer tax credits were extended again, by the American Taxpayer Relief Act of 2012, for clothes washers, refrigerators, and dishwashers manufactured between January 1, 2012 and December 31, 2013.

Manufacturers who produce these appliances receive the credits for increasing their production of qualifying appliances. These credits had several efficiency tiers in 2011. For 2012-2013, credits for the higher tiers remain but were eliminated for the lowest (least efficient) tiers for clothes washers and dishwashers. The credit amounts applied to each unit manufactured. The credit to manufacturers of qualifying clothes washers, refrigerators and dishwashers was capped at $75 million for the period of 2008-2010. However, the most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 wcf) models was not subject to the cap. The credit to manufacturers was capped at $25 million for 2011, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 WCF) exempted from this cap.[g]

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[g] For more information on federal tax credits for manufacturers see the following websites: https://programs.dsireusa.org/system/program/detail/1273/energy-efficient-appliance-manufacturing-tax-credit, https://energytaxincentives.org/

17A.6.2 State Tax Credits

The States of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the States of Kentucky, Michigan and Indiana began offering such credits in 2009. The Oregon Department of Energy (ODOE) has disaggregated data on taxpayer participation in credits for eligible products. (See the discussion in chapter 17, Section 17.3.3, on tax credit data for clothes washers.) Montana's Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trends and found them congruent with its analysis of Oregon's clothes washer tax credits.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977. The Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, which significantly increased participation in the program. The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. Beginning in 2012 a Tax Credit Extension Bill (HB3672) eliminated refrigerators, clothes washers, dishwashers, air conditioners, and boilers from the RETC program, leaving credits for water heaters, furnaces, heat pumps, tankless water heaters, and heat pump water heaters.[20, 21] The technologies recognized by the Oregon Department of Energy as "premium efficiency" were eligible for a tax credit of $0.60 per kWh saved in the first year (up to $1,500).[20,]

Montana had an Energy Conservation Tax Credit for residential measures starting in1998.[22] The tax credit covered various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit could be used for products installed in new construction or remodeling projects. The tax credit covered only the part of the cost and materials that exceeded established standards of construction.

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