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TECHNICAL SUPPORT DOCUMENT: ENERGY CONSERVATION STANDARDS FOR CONSUMER PRODUCTS: REFRIGERATORS, FURNACES, AND TELEVISION SETS

including
Environmental Assessment (DOE/EA-0372)
Regulatory Impact Analysis

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U.S. Department of Energy
Assistant Secretary, Conservation
and Renewable Energy
Building Equipment Division

ENVIRONMENTAL ASSESSMENT FOR PROPOSED ENERGY CONSERVATION STANDARDS FOR TWO TYPES OF CONSUMER PRODUCTS; REFRIGERATORS, REFRIGERATOR-FREEZERS, AND FREEZERS; SMALL GAS FURNACES; AND A PROPOSED "NO STANDARD" STANDARD FOR TELEVISION SETS

1 INTRODUCTION AND SUMMARY

This environmental assessment (EA) evaluates the environmental impacts resulting from new or amended energy-efficiency standards for refrigerators, refrigerator-freezers, freezers, small gas furnaces, and television sets as mandated by the National Appliance Energy Conservation Act of 1987 (NAECA, 1987). A complete description of the Engineering and Economic Analysis of the proposed standards may be found elsewhere in the Technical Support Document (TSD). Four of the 14 scenarios for product design changes described in the Engineering Analysis of the TSD are chosen for environmental assessment based on their relative importance as design measures. Values for energy savings that result from product design changes are also taken from the TSD.

The two main environmental concerns addressed are emissions from fossil fuel-fired electricity generation and the chlorofluorocarbons used in the production of rigid insulation foam. Each of the 12 design options for refrigerators and freezers result in decreased electricity use and, therefore, reduced power plant emissions. Design changes that call for additional rigid foam insulation per appliance are of interest because they affect chlorofluorocarbon consumption. There is strong evidence that chlorofluorocarbons migrate to the stratosphere, break down, and catalyze the destruction of stratospheric ozone.

The four scenarios analyzed are product design levels 3, 7, and 8 for refrigerators and freezers and a 78% annual fuel use efficiency (AFUE) requirement for small gas furnaces. Emission savings from the Level 3 scenario for television set efficiencies are also presented, although these results are not discussed in detail.

In the Level 3 scenario, all refrigerator and freezer doors would be changed to include rigid foam insulation one and a half inches thick. In the Level 7 scenario, all refrigerator and freezer doors would be changed to include rigid foam insulation two inches thick. In the Level 8 scenario, the insulating value of the foam itself in the walls and doors of appliances would be improved from a conductivity factor, K, of 0.125 (Btu-inch)/(hr-ft^2-°F) to a K value of 0.1. Levels 7 and 8 refrigerators and freezers also include 5.3 EER compressors and more efficient fans. The design changes to small gas furnaces associated with an efficiency improvement to 78% are installing an intermittent ignition device and a fan for induced draft combustion. The 12 design changes for refrigerators and freezers and the three increased efficiency designs for small gas furnaces are described in greater detail in the TSD.

Levels 1 and 2 designs for refrigerators and freezers are not analyzed because they do not call for changes in the quantity or nature of rigid foam insulation used per unit; energy savings attributed to Levels 1 and 2 are achieved through the use of 4.5 and 5.0 EER compressors, respectively. Power plant emissions would be abated as a result of Levels 1 and 2, but in smaller amounts than for Levels 3-12, which result in greater energy savings. Levels 4, 5, and 6 are not analyzed because they do not use more CFCs than the Level 3 scenario and the reduction in emissions are between the those for the Level 3 and the Level [illegible] scenarios. Levels 9 through 11 are not analyzed because they are not addressed [illegible] the TSD and therefore values for estimated energy savings and numbers of app[illegible] ances sold are not available for estimating environmental impacts. Level [illegible] excluded because it is a lower priority design measure than the levels analy[illegible]

The proposed efficiency standards will decrease air pollution by de[illegible] future energy demand. The greatest decreases in air pollution will be in [illegible] oxides (listed in equivalent weight of sulfur dioxide, or SO_2). For the [illegible] scenario in the year 2010, the estimated SO_2 reduction will be 202,000 [illegible] reduction represents 1.2% of the U.S. SO_2 emissions expected to be [illegible] power plants in that year if no appliance standards are established (P[illegible]

Although the quantity of raw materials used per appliance will [illegible] tively constant, increased energy efficiency is expected to slightly [illegible] number of appliances sold, resulting in small increases in raw [illegible] This demand increase is estimated by the Consumer Impact Analy[illegible] The main effect of increased appliance production is the SO_2 em[illegible] duction. The increase is small, however, in comparison to the SO[illegible] burning avoided at power plants. The contribution from steel production is included in the estimates for net SO_2 decreases resulting from design changes in refrigerators and freezers.

The Level 8 decrease in nitrogen dioxide (NO_2) emissions for the year 2010 is estimated at 134,000 tons. This decrease in NO_2 emissions represents 1.3% of the total NO_2 emissions expected to be emitted by power plants in that year without new appliance standards. Emissions savings projected from Level 7 design changes are nearly as great as the Level 8 savings because the only applicable difference between the two scenarios is a slightly larger number of appliances sold in the Level 8 scenario. Emissions savings from Level 3 design changes amount to about half those from the Level 8 design changes.

Cumulative SO_2 emissions reductions from increased efficiency of small gas furnaces is only about 3% of the reductions from Level 8 refrigerator and freezer design changes, or about 110,000 tons cumulative between 1993 and 2015. For Level 3 television set standards, the reduction of SO_2 and NO_2 emissions amounts to 10% of that from the Level 8 standards for refrigerators and freezers.

Another consequence of standards will be reduction of carbon dioxide (CO_2) emissions. CO_2 from fossil fuel burning is considered an environmental hazard because elevated CO_2 concentrations in the atmosphere are believed to trap heat from the sun that has been absorbed by the Earth and reradiated. This "greenhouse effect" is expected to gradually raise the mean global temperature. The Level 8 scenario is estimated to reduce worldwide CO_2 emissions, for each of the years 2010 through 2015, by an amount equivalent to 0.2% of the 1985 base figure for anthropogenic CO_2 emissions, which is 5.84×10^9 tons of carbon per year (Harte, 1985).

An additional effect of some design change scenarios is the increased consumption of chlorofluorocarbons (CFCs). The chlorofluorocarbon R-11 is contained in the rigid foam insulation used in the walls and doors of appliances. Use of R-11 would increase if manufacturers increased the thickness of appliance insulation. Another CFC, R-12, is the heat exchange fluid used in refrigerators and freezers. The use of R-12 would increase if more refrigerators and freezers were produced in response to an increased demand for the more efficient appliances. During the year 2010, Level 8 increases in CFC consumption attributed to standards are estimated at 1.0% of the 1985 total U.S. R-11 and R-12 consumption (Hammitt, 1986).

Other environmental effects related to a standards-induced decrease in electricity generation are relatively insignificant compared to the decreases in SO_2, NO_2, and CO_2.

An in-depth analysis of particulate emissions is not included in this assessment because they are insignificant compared to sulfur and nitrogen oxide emissions. Current electricity generating methods are far cleaner than those of the past. In 1984, power plants contributed only 7% of U.S. total particulate emissions as compared to contributions of 83% and 34% to total SO_2 and NO_2 emissions, respectively (EPA, 1986).

More efficient small gas furnaces will decrease the amount of gas or oil burned within some homes, thereby decreasing combustion effects on indoor air quality. Indoor air problems are usually due to a combination of factors, including a tight house envelope, cigarette smoke, ventilation methods, water use habits, and radon diffusion from soil. In comparison to the above factors, incremental changes in combustion gases used have a small effect on indoor air quality.

2 METHODS OF ESTIMATING ENVIRONMENTAL IMPACTS

The greatest impacts of the proposed standards are the result of generat[illegible] less electricity. Power plants' main environmental effects on air and water re[illegible] from emissions of sulfur oxides (SO_x), nitrogen oxides (NO_x), and carbon di[illegible] (CO_2). The symbols SO_2 and NO_2 represent all emissions of SO_x and [illegible] expressed in the equivalent weights of SO_2 and NO_2, respectively. Carbon d[illegible] emissions are commonly expressed in tons of carbon.

The efficiencies of refrigerators and freezers can be improved by using [illegible] insulation in their doors. If this design option is chosen by the indu[illegible] response to standards, chlorofluorocarbon consumption will increase. CF[illegible] estimated on the basis of refrigerator and freezer dimensions and the [illegible] additional CFC required to increase the volume of rigid insulation foam [illegible] the design options proposed requires the use of additional R-12 (a CFC [illegible] refrigerant) per appliance. A secondary effect, the change in shipmen[illegible] from standards, is also considered.

Sulfur and Nitrogen Oxide Emissions

For each of the scenarios analyzed for their environmental impacts (Level 3, Level 7, and Level 8 in refrigerators and freezers, 78% AFUE small gas furnaces, and Level 3 efficiencies for televisions), emissions abated from fossil fuel-burning power plants are considered.

In analyzing the impacts of Level 3, 7, and 8 design changes to refrigerators and freezers, increased sulfur emissions to come from increased steel production are also considered. As mentioned earlier in this report, these increases in steel production result from slight increases in the number of appliances sold, equated to an increase in the number of appliances manufactured. No changes in the amount of steel used per refrigerator or freezer are expected.

Analysis of the impacts resulting from 78% AFUE small gas furnaces includes the consideration of SO_2 from in-home combustion of gas and oil.

Figures for energy saved by reduced electric generation are taken from the TSD. Primary energy saved from electric generation is allocated among the categories of coal on the one hand, and gas plus oil on the other, in the ratios of 0.53 and 0.47, respectively, as estimated in supporting material for the Electric Utility Analysis, also in the TSD. This disaggregation into coal and oil-plus-gas is depicted in Figure 1. In order to capture the effects of cleaner-burning power plants in future years, emission rates for power plant fuel burning are calculated from projected emissions data and the projected quantities of the corresponding fuels used, as described in Placet, et al. (1986). Gas and oil are combined because, from an electric utility perspective, they are interchangeable. Linear interpolation and extrapolation are used to derive emissions rates for years not covered in the report.

Sulfur dioxide emissions from steel production are estimated assuming 100 pounds of steel per refrigerator or freezer (Mooz, 1982). An SO_2 emissions rate for steel production is calculated from the "National Air Pollutant Emission Estimates, 1940-1985," (EPA, 1986), along with its supporting materials, and a value for 1985 national steel production from the U.S. Department of Commerce (U.S. Department of Commerce, 1986)*. SO_2 emissions from steel production are multiplied by the tons of steel to be used in manufacturing the additional appliances in the Level 3, 7, and 8 scenarios.

* Uncertainty arises because EPA had to make assumptions about the furnace types used to produce steel and about the sulfur content of the coal burned to generate the electricity for steel production.

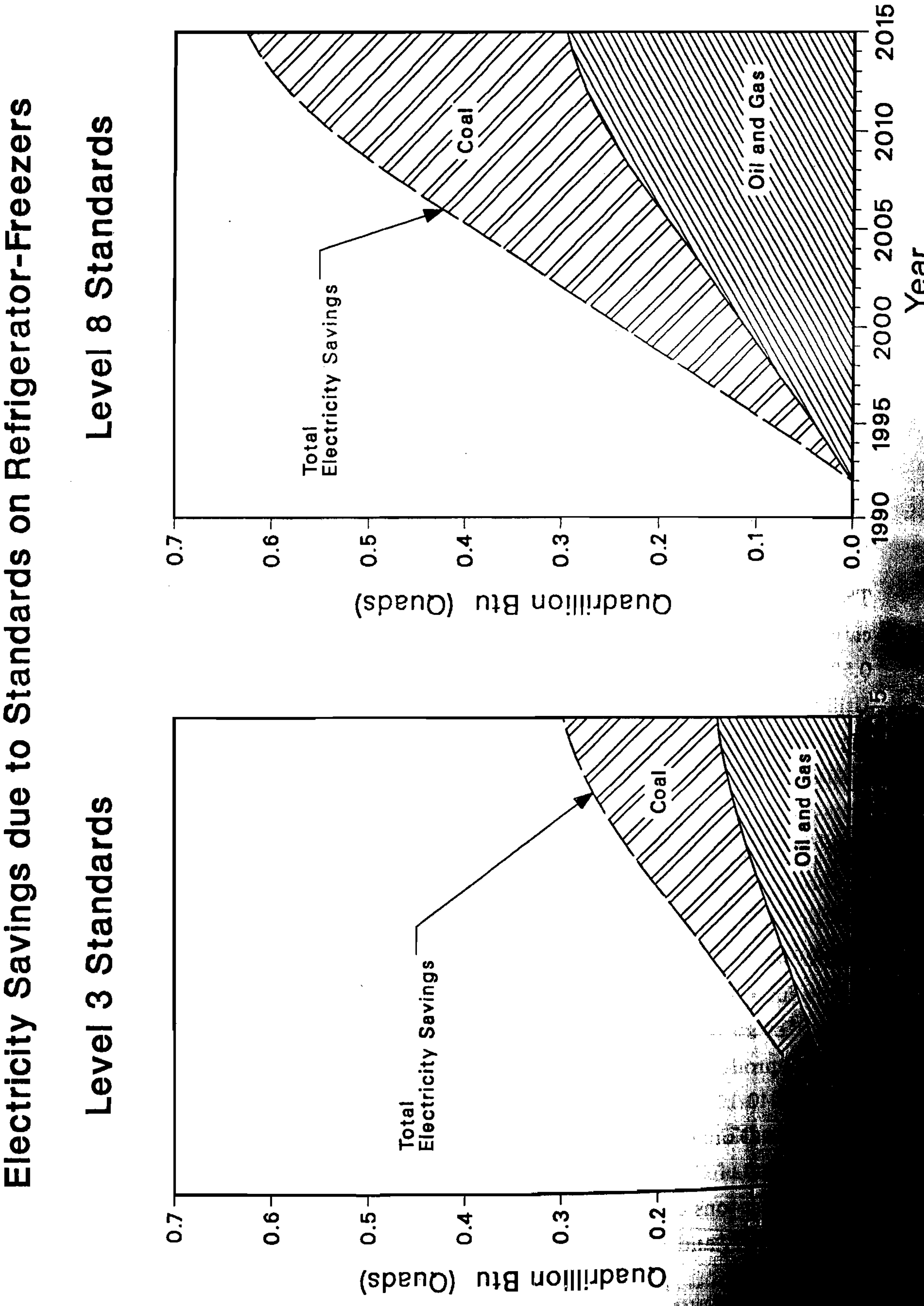

Figure 1. Electricity Savings Due to Standards on Refrigerator-

The values for SO_2 savings from in-home gas and oil combustion are produced by multiplying in-home fuel savings for gas and oil by corresponding emission rates for furnace operation, taken from Surprenant, et al. (1979).

Methods and data sources for calculating changes in NO_2 emissions are identical to those for SO_2 emissions with the exception of emissions from steel production. Unlike in the scenario for SO_2, no significant NO_2 emissions are expected from increased steel production.

2.2 Carbon Dioxide Emissions

Values for CO_2 abated are the sum of the CO_2 savings from coal-, gas-, and oil-fired power plants and, for the 78% AFUE small gas furnace scenario only, CO_2 emissions from in-home combustion of gas and oil. The energy saved from electricity generation is apportioned between coal and gas or oil as in the calculation of SO_2 and NO_2. In addition, gas and oil are disaggregated into relative shares of 0.70 and 0.30, respectively. These shares are the averages of the relative quantities of these fuels to be used for electrical generation in the years 1990 through 1995, as estimated by the North American Electric Reliability Council (NERC, 1985). The energy values of the fuels saved are translated into tons of carbon using carbon/Btu values from the *Carbon Dioxide Review*, (Clark, 1982). The data for a more accurate method of estimated relative gas and oil shares concerning order of dispatch in the various NERC regions are not available. This disaggregation into fuel shares should therefore be taken only as a rough representation of power plant fuel choices on the margin.

2.3 Chlorofluorocarbon Consumption

Design change level 3 involves adding foam to the doors of refrigerator-freezers and freezers to a thickness of 1.5 inches. This would require additional foam in the doors of some models and the use of foam to replace fiberglass in others. The Level 7 design change specifies increasing the thickness of the foam used in the appliance doors to 2.0 inches. Design change level 8 includes the 2.0 inch thick insulation in appliance doors called for by Level 7 and also specifies an increase in the insulating value of the foam itself. Because they called for adding foam insulation to the doors of refrigerators and freezers, all three design change scenarios for these appliances involve a change in the amount of CFCs used per appliance. The 78% AFUE small gas furnace scenario does not involve CFC production or consumption.

Average refrigerator and freezer dimensions are used to estimate the dimensions of foamed areas, which in turn are used to estimate changes in CFC use. These estimated dimensions of foamed areas remain constant in all three scenarios while the thickness of door insulation varies; the only exception is an increase in the foamed area for refrigerator-freezers and freezers that have no door foam in the base case scenario.

The volume of foam is estimated for each of ten product classes. The ten classes fit into six groups of height, width, and depth. For example, group D includes all side-by-side refrigerator-freezers. Appendix A specifies the classes included in each group and lists the estimated dimensions of foamed areas for groups A through F.

The estimates of foamed areas for appliance groups C, D, and E are based on appliance dimensions as outlined in the Engineering Analysis in the TSD.

In order to estimate foamed areas for appliances in groups A, B, and F, average adjusted volumes for the specified models are first obtained from the Association of Home Appliance Manufacturers. These average adjusted volumes are used to identify the most appropriately sized models for which exterior dimensions [illegible] listed by the California Energy Commission, (CEC, 1987). Appliance dimensions from the CEC report are then used to estimate dimensions of foamed areas.

When interior appliance dimensions are used to estimated the size of fo[illegible] areas, 1.0 inch is added where appropriate in order to account for extra foam [illegible] around corners. When exterior appliance dimensions are used to estimate [illegible] of foamed areas, 1.0 inch is subtracted where appropriate to account for the [illegible] lap of foamed areas around corners. It is assumed that the bottom edge [illegible] lated areas begins 6.5 inches above floor level for each of the refrigerat[illegible] and freezer models except freezers. The bottom edge of insulated areas [illegible] freezers is estimated to begin 2 inches above floor level.

Volumes of foam are converted into pounds of the CFC R-11 using [illegible] 1.5 pounds of foam per cubic foot (Hammitt, 1986) and 0.2 pounds [illegible] pound of foam. The ratio of 0.2 pounds of R-11 per pound of fo[illegible] from the current annual quantity of R-11 used by manufacturers [illegible] and freezers (14,835,000 pounds--AHAM, 1987) along with the [illegible] appliances manufactured (7,145,000 appliances--AHAM, 1987) and [illegible] volumes of foam calculated as outlined above and weighted by shipment (Roman, 1987 and AHAM, 1986)

The total change in CFCs is the sum of CFCs from increased foam use per appliance and increased CFCs from the production of a greater number of appliances. The former contribution to increased CFC use is the product of per unit R-11 increases and the base case number of appliances shipped. The latter contribution to increased CFC use includes per unit R-11 in the foam insulation and R-12 refrigerant in the additional appliances shipped. Values for the amounts of the R-12 used in refrigerators and freezers are 210 grams and 280 grams, respectively (Hammitt, 1986). Where R-12 values are included in totals, they are listed in terms of their ozone damage potential (0.79) relative to R-11 (Mooz, 1982).

3 REFRIGERATORS AND FREEZERS

3.1 Level Three Design Changes

The Level 3 design changes are the addition of rigid insulating foam to the doors of refrigerators and freezers to a thickness of one and a half inches.

3.1.1 Sulfur and Nitrogen Oxide Emissions

Changes in the amounts of SO_2 and NO_2 emitted result mainly from greater refrigerator and freezer efficiency and resulting decreases in the amount of electricity generated by fossil fuel-burning plants. SO_2 emissions are also affected by increased steel production because of slightly increased demand for the more efficient appliances. No additional steel is expected to be used per appliance.

Sulfur dioxide emissions would be decreased by a cumulative total of 1,540,000 tons between 1993 and 2015 in the Level 3 scenario. Figures for changes in SO_2 emissions are listed in Table 1. In the year 2000, decreases in sulfur dioxide will represent roughly 0.3% of the SO_2 emissions estimated to come from power plants in that year. In the year 2010, decreases in SO_2 emissions will represent about 0.6% of the SO_2 emissions estimated to come from power plants in that year if standards are not established.

There is evidence that decreases in sulfur emissions are followed by proportional decreases in acid deposition (Oppenheimer, 1983). Quantifying and qualifying the resulting abatement of environmental damage is considerably more difficult. An attempt is made in the section titled "Valuing Decreases in Acid Precipitation".

Level 3 design changes to refrigerators would result in an estimated decrease in NO_2 emissions of 996,000 tons between 1993 and 2015. Changes in NO_2 emissions are also listed in Table 1. NO_2 decreases would represent 0.4% and 0.6% of the NO_2 emissions estimated to come from power plants in the years 2000 and 2010, respectively.

3.1.2 Carbon Dioxide Emissions

The cumulative reduction in CO_2 emissions from Level 3 design changes is 88 million tons of carbon. For the year 2000, the estimated CO_2 reduction is 2.6 million tons of carbon. In 2010, the estimated CO_2 reduction is 5.8 million tons of carbon, or about 0.1% of estimated 1985 worldwide anthropogenic CO_2 emissions. In other words, by 2010, Level 3 design changes will decrease annual global CO_2 emissions by one one-thousandth of current levels.

3.1.3 Chlorofluorocarbon Consumption

The chlorofluorocarbon with the greatest ozone destruction potential, R-11, is used as a blowing agent in producing polyurethane foam, the insulation used in the walls of refrigerators and freezers. Most of the Level 3 increases in CFC use can be attributed to the R-11 used as more insulation is blown into the doors of refrigerators and freezers. Similar to the estimation of SO_2 emissions, estimations of CFC use include the effects of increased demand for efficient appliances. In the case of CFCs, this includes the manufacturing of additional appliances including R-11 in their foam walls and R-12 as a heat exchange fluid. R-12 is estimated to be 0.79 times as damaging to the ozone as R-11 (Mooz, 1982).

Level 3 design changes would result in an average CFC-11 consumption of 2.71 pounds per refrigerator-freezer and 1.95 pounds per freezer, increases of 0.28 pounds and 0.12 pounds of CFC-11, respectively. Adding in additional R-12 used in the Level 3 scenario and summing use between 1993 and 2015 yields a total increase of 66 million pounds of CFC-11 equivalent. In the year 2010, the estimated increase of 3.1 million pounds represents 0.7% of the 1985 U.S.

emissions of R-11 and R-12.

3.2 Level Seven Design Changes

The Level 7 design changes are the addition of rigid insulating foam to the doors of refrigerators and freezers to thickness of two inches.

3.2.1 Sulfur and Nitrogen Oxide Emissions

Sulfur dioxide emissions would be decreased by a cumulative total of 2,910,000 tons between 1993 and 2015. Figures for changes in SO_2 emissions are listed in Table 3. In the year 2000, decreases in sulfur dioxide will represent roughly 0.6% of the SO_2 emissions estimated to come from power plants in that year if no efficiency standards are established. In the year 2010, decreases in SO_2 emissions will represent about 1.1% of the SO_2 emissions estimated to come from power plants in that year.

Level 7 design changes to refrigerators and freezers would result in an estimated decrease in NO_2 emissions of 1,880,000 tons between 1993 and 2015 (see Table 3.). NO_2 decreases would represent 0.7% and 1.2% of the NO_2 emissions estimated to come from power plants in the years 2000 and 2010, respectively.

3.2.2 Carbon Dioxide Emissions

The cumulative reduction in CO_2 emissions from Level 7 design changes is 166 million tons of carbon. For the year 2000, the estimated CO_2 reduction is 4.9 million tons of carbon. In 2010, the estimated CO_2 reduction is 11 million tons of carbon, or about 0.2% of estimated 1985 worldwide anthropogenic CO_2 emissions expected if no appliance efficiency standards are established.

3.2.3 Chlorofluorocarbon Consumption

The production of refrigerator-freezers would require 2.84 pounds of R-11 for wall and door insulation in the Level 7 scenario, an increase of 0.41 pounds over the base case scenario. Freezers would require the use of 2.06 pounds of R-11 for rigid insulation, an increase of 0.24 pounds per unit. Level 7 increase in the chlorofluorocarbons R-11 and R-12, listed in equivalent amounts of R-11, sums to 102 million pounds of R-11 equivalent for the years 1993 and 2015. In the year

2010, the estimated increase of 4.8 million pounds represents 1.0% of the 1985 U.S. emissions of R-11 and R-12.

3.3 Level Eight Design Changes

The Level 8 design change includes the Level 7 increase in foam insulation to two inches in appliances doors as well as increasing the insulating quality of the foam itself. The current insulation conductivity factor for the foam used in appliance walls and doors is $K = 0.125$ (Btu-inch)/(hr-ft^2- °F). Level 8 design changes would require a change in the K factor from 0.125 to 0.10. Level 8 refrigerators and freezers also include 5.3 EER compressors and more efficient fans. Better insulation for refrigerators and freezers would result in decreased electricity consumption and a corresponding decrease in the burning of fossil fuels.

The effects of Level 8 design changes include the two contributions. SO_2 changes will result from decreased fossil fuel burning in power plants as well as an from increased steel production. Increased steel production is a result of greater demand for the more efficient appliances.

3.3.1 Sulfur and Nitrogen Oxide Emissions

Net SO_2 emissions abated between 1993 and 2015 sum to 3.2 million tons. During the year 2000, 113,000 tons of SO_2 will be abated, representing roughly 0.6% of the SO_2 emissions estimated to come from power plants in that year. By the year 2010, SO_2 emissions abated will be about 1.2% of the estimated annual SO_2 emissions from power plants if no new appliance efficiency standards are established.

Avoided NO_2 emissions resulting from Level 8 design changes are estimated as those emissions saved from decreases in fossil fuel burning in electric power plants. No significant NO_2 contribution is expected from the increases in steel production associated with increases in product demand. The cumulative NO_2 emissions avoided for the 23-year period studied are 2.1 million tons. Annual quantities of NO_2 avoided are 66,000 tons (0.7% of estimated power plant emissions) and 134,000 tons (1.3%) for the years 2000 and 2010, respectively.

3.3.2 Carbon Dioxide Emissions

Level 8 changes in CO_2 emissions add up to 185 million tons of carbon for the years 1993 through 2015. CO_2 savings are listed in Table 6. The quantity of CO_2 saved increases each year through the period studied, reaching 14.3 million tons of carbon in the year 2015. These savings represent 0.2% of estimated 1985 worldwide CO_2 emissions.

3.3.3 Chlorofluorocarbon Consumption

A change from a K factor from 0.125 to 0.10 involves changing the amount of CO_2 and water used, and does not affect the amount of R-11 used. In other words, the amount of R-11 used per appliance does not change from the Level 7 to the Level 8 scenario. The only difference between values for increased CFC consumption between these two scenarios results from the difference in the number of appliances sold. Values for CFC increases in the Level 8 scenario are listed in Table 6.

4 SMALL GAS FURNACES

The effects considered in determining the environmental impacts of more efficient small gas furnaces are a decrease in electricity generated at fossil fuel-burning power plants and decreases in gas and oil burned in homes. Small decreases in electricity consumption will occur as some households shift from electric heating to small gas furnaces.

Although slight increases in shipments of small gas furnaces are expected, increases in the materials used in producing these furnaces will be offset by decreases in the the materials used in producing the larger furnaces and the electric heating devices that the small gas furnaces will replace.

A change in furnace efficiency to 78% does not affect the emissions from gas or oil burned in these furnaces. Although changes in emissions rates may occur along with condensation of some of the vapor in the flue gases, this condensation does not occur until efficiencies in the range of 82-84% are reached (DeWerth, 1988).

4.0.1 Sulfur and Nitrogen Oxide Emissions

The decrease in SO_2 emissions resulting from the 78% AFUE standard amounts to 110,000 tons between 1993 and 2015, as shown in Table 7. Annual decreases in SO_2 emissions amount to 2.4% and 4.2% of the emissions estimated to come from residential fuel combustion during the years 2000 and 2010, respectively if no new efficiency standards are adopted.

NO_2 emissions avoided between 1993 and 2010 amount to 80,000 tons. Annual percent decreases for the years 2000 and 2010 are 0.6% and 1.3% of U.S. NO_2 emissions from residential fuel combustion, respectively assuming no new appliance standards are established.

4.0.2 Carbon Dioxide Emissions

Decreases in CO_2 emissions resulting from increased small gas furnace efficiencies add up to 8.5 tons of carbon through the year 2015. The greatest annual savings, achieved in the later years of the period studied, are about one ten-thousandth of 1985 global CO_2 emissions.

5 TELEVISION SETS

The television efficiency Level 3 scenario, which offers the greatest energy savings for televisions, decreases electricity use by about 0.73 quadrillion Btus for the years 1992 through 2015. These electricity savings translate into cumulative savings of 309,000 tons of SO_2 and 193,000 tons of NO_2. These reductions are each about 10% of the corresponding reductions from Level 8 refrigerator-freezer and freezer efficiencies.

However, the proposed no standard for televisions results in no impact on the environment since it will not change the status quo. DOE is unaware of any state or local energy conservation standard concerning television sets that would be preempted by the "no standard" standard. The only state standard of which DOE is aware is the New York State standard that bans the "instant on" feature of tube type televisions. However, since tube type television sets are no longer manufactured, such standards currently have no effect.

6 EVALUATION OF ENVIRONMENTAL IMPACTS

6.1 Valuing Decreases in Acid Precipitation

Sulfur dioxide is the major contributor to acid precipitation in the U.S. After a series of reactions with atmospheric gases and water, SO_2 forms sulfuric acid. More than half of the domestic SO_2 emitted as a result of human activities comes from coal burned in power plants. The next greatest contributor to acid precipitation is nitrogen dioxide. One-third of the domestic NO_2 emitted from human activities comes from electricity generating facilities (Placet, 1986).

Attaching values to incremental changes in acid precipitation is difficult. The effects of acid deposition on a given lake or forest depend on a variety of factors, including distance from pollutant source, buffering capacity, surrounding topography, rate of snow melt, soil or sediment type, etc. Acid precipitation can have negligible effects in buffered natural systems—those containing substances that take up or react with acids—until the buffering capacity is used up. Continued acid precipitation brings water and forest ecosystems closer to their buffering capacity limits, which can greatly affect living systems. Allowing a body of water to return to its natural state of alkalinity (buffering capacity) may require tens to thousands of years. In attempting to quantify the effects of acid precipitation, it is therefore important to consider cumulative effects that may not currently be obvious.

Some effects on humans resulting from adding acid to ecosystems are: decreases in fishing productivity, forest productivity, farming productivity, recreational opportunities, and the degradation of susceptible buildings and monuments.

6.2 Perspectives on Changes in Carbon Dioxide Emissions

Atmospheric CO_2 is relatively transparent to incoming solar energy (short-wave radiation) but impedes outgoing solar energy, which is in the form of heat (long-wave radiation). The net result of elevated CO_2 concentrations is a trapping of heat near the Earth's surface. This trapping of heat, referred to as the "greenhouse effect", raises the mean global temperature. Because of human activity, the CO_2 concentrations in the atmosphere have increased from 290 parts per million (ppm) before the industrial era to about 335 ppm in 1979. Expected results of a global temperature change are: perturbed air and ocean currents, perturbed precipitation patterns, changes in the gaseous equilibrium between the atmosphere and the biosphere, and the melting of some of the ice now covering polar lands and oceans followed by a rise in sea level (Council on Environmental Quality, 1981).

A doubling of the pre-industrial levels of CO_2 is projected to occur in the late part of the next century. The process of controlling CO_2 concentrations is dependent on two time determinants: lead times involved in changing current trends in fossil fuel use and lag times in environmental systems. If the goal were to keep CO_2 concentrations from exceeding 500 ppm, even a growth rate in fossil fuel use of 1.5% per year (compared to a growth rate of 2.3% in 1980) could not continue much beyond the end of this century (Clark, 1982).

6.3 Perspectives on Changes in Chlorofluorocarbon Consumption

Chlorofluorocarbon use could upset the atmospheric equilibrium of ozone, a compound that partially screens ultraviolet radiation entering the Earth's atmosphere. Increases in UV radiation translate into increased risks of skin cancer in humans, varied adverse effects on marine and terrestrial organisms and ecosystems, and a greater threat of altering global climatic patterns by contributing to the greenhouse effect.

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Table 1. Refrigerators and Freezers — Level Three
Changes in Sulfur and Nitrogen Dioxide Emissions

SO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. SO_2 Power Plant Emissions
1995	-18,700	-2,900	+19	-21,600	-0.13
2000	-46,200	-7,800	+18	-54,000	-0.30
2005	-64,500	-13,700	+16	-78,100	-0.45
2010	-78,200	-17,800	+20	-96,000	-0.56
2015	-78,200	-20,000	+29	-100,000	-0.62

Cumulative SO_2 reduction, 1993-2015 = 1,540,000 tons.

NO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. NO_2 Power Plant Emissions
1995	-8,500	-3,400	-	-11,800	-0.14
2000	-22,100	-9,100	-	-31,200	-0.35
2005	-34,400	-15,000	-	-49,400	-0.51
2010	-46,200	-17,800	-	-64,000	-0.62
2015	-51,900	-21,500	-	-73,400	-0.69

Cumulative NO_2 reduction, 1993-2015 = 996,000 tons.

Table 2. Refrigerators and Freezers — Level Three
Changes in Carbon Dioxide and Chlorofluorocarbon Emissions

CO_2

Thousands of Tons of Carbon

Year	Abated From Coal Generation	Abated From Gas Generation	Abated From Oil Generation	Net Change	Percent of 1985 World Emissions
1995	-617	-219	-120	-957	-0.02
2000	-1,670	-593	-326	-2,590	-0.04
2005	-2,740	-972	-534	-4,240	-0.07
2010	-3,770	-1,340	-735	-5,840	-0.10
2015	-4,390	-1,560	-855	-6,800	-0.12

Cumulative CO_2 reduction, 1993-2015 = 88 million tons of carbon.

CFC

All CFC values expressed in pounds of R-11 equivalent.

Year	Increase From Design Changes	Increase From Increased Shipments	Net Change	Percent of U.S. 1985 R-11 & R-12*
1995	+2,400,000	+275,000	+2,670,000	+0.58
2000	+2,400,000	+254,000	+2,650,000	+0.57
2005	+2,520,000	+227,000	+2,740,000	+0.59
2010	+2,800,000	+289,000	+3,090,000	+0.67
2015	+2,980,000	+407,000	+3,390,000	+0.73

Cumulative CFC increase, 1993-2015 = 66 million pounds of R-11 equivalent.

* Sum of estimated U.S. use of R-11 and R-12 (Hammitt, 1986).

Table 3. Refrigerators and Freezers — Level Seven
Changes in Sulfur and Nitrogen Dioxide Emissions

SO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. SO_2 Power Plant Emissions
1995	-35,400	-5,500	+33	-40,800	-0.24
2000	-87,400	-14,800	+32	-102,000	-0.57
2005	-122,000	-25,800	+28	-148,000	-0.84
2010	-148,000	-33,700	+35	-181,000	-1.06
2015	-151,000	-37,800	+50	-188,000	-1.17

Cumulative SO_2 reduction, 1993-2015 = 2,910,000 tons.

NO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. NO_2 Power Plant Emissions
1995	-16,000	-6,400	-	-22,300	-0.27
2000	-41,800	-17,200	-	-59,000	-0.66
2005	-64,900	-28,400	-	-73,300	-0.97
2010	-87,200	-33,700	-	-120,000	-1.18
2015	-98,200	-40,700	-	-139,000	-1.30

Cumulative NO_2 reduction, 1993-2015 = 1,880,000 tons.

Table 4. Refrigerators and Freezers — Level Seven
Changes in Carbon Dioxide and Chlorofluorocarbon Emissions

CO_2

Thousands of Tons of Carbon

Year	Abated From Coal Generation	Abated From Gas Generation	Abated From Oil Generation	Net Change	Percent of 1985 World Emissions
1995	-1,170	-414	-228	-1,810	-0.03
2000	-3,170	-1,120	-617	-4,900	-0.08
2005	-5,180	-1,840	-1,010	-8,020	-0.14
2010	-7,120	-2,530	-1,390	-11,000	-0.19
2015	-8,300	-2,940	-1,620	-12,900	-0.22

Cumulative CO_2 reduction, 1993-2015 = 166 million tons of carbon.

CFC

All CFC values expressed in pounds of R-11 equivalent.

Year	Increase From Design Changes	Increase From Increased Shipments	Net Change	Percent of U.S. 1985 R-11 & R-12*
1995	+3,650,000	+496,000	+4,150,000	+0.90
2000	+3,660,000	+460,000	+4,120,000	+0.89
2005	+3,830,000	+412,000	+4,240,000	+0.92
2010	+4,260,000	+524,000	+4,780,000	+1.03
2015	+4,530,000	+742,000	+5,280,000	+1.14

Cumulative CFC increase, 1993-2015 = 102 million pounds of R-11 equivalent.

* Sum of estimated U.S. use of R-11 and R-12 (Hammitt, 1986).

Table 5. Refrigerators and Freezers — Level Eight
Changes in Sulfur and Nitrogen Dioxide Emissions

SO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. SO_2 Power Plant Emissions
1995	-39,300	-6,100	+36	-45,400	-0.26
2000	-97,200	-16,400	+34	-113,000	-0.63
2005	-135,000	-28,700	+30	-164,000	-0.94
2010	-164,000	-37,400	+38	-202,000	-1.18
2015	-167,000	-42,000	+54	-209,000	-1.30

Cumulative SO_2 reduction, 1993-2015 = 3,240,000 tons.

NO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	From Increased Steel Production (tons)	Net Change (tons)	Percent of Annual U.S. NO_2 Power Plant Emissions
1995	-17,800	-7,100	-	-24,800	-0.30
2000	-46,400	-19,200	-	-65,600	-0.73
2005	-72,200	-31,500	-	-104,000	-1.08
2010	-96,900	-37,400	-	-134,000	-1.31
2015	-109,000	-45,200	-	-154,000	-1.45

Cumulative NO_2 reduction, 1993-2015 = 2,090,000 tons.

Table 6. Refrigerators and Freezers — Level Eight
Changes in Carbon Dioxide and Chlorofluorocarbon Emissions

CO_2

Thousands of Tons of Carbon

Year	Abated From Coal Generation	Abated From Gas Generation	Abated From Oil Generation	Net Change	Percent of 1985 World Emissions
1995	-1,300	-460	-253	-2,010	-0.03
2000	-3,520	-1,230	-686	-5,450	-0.09
2005	-5,750	-2,040	-1,120	-8,920	-0.15
2010	-7,920	-2,810	-1,540	-12,300	-0.21
2015	-9,230	-3,270	-1,800	-14,300	-0.24

Cumulative CO_2 reduction, 1993-2015 = 185 million tons of carbon.

CFC

All CFC values expressed in pounds of R-11 equivalent.

Year	Increase From Design Changes	Increase From Increased Shipments	Net Change	Percent of U.S. 1985 R-11 & R-12*
1995	+3,650,000	+528,000	+4,180,000	+0.90
2000	+3,660,000	+490,000	+4,150,000	+0.90
2005	+3,830,000	+440,000	+4,270,000	+0.92
2010	+4,260,000	+561,000	+4,820,000	+1.04
2015	+4,530,000	+796,000	+5,330,000	+1.15

Cumulative CFC increase, 1993-2015 = 103 million pounds of R-11 equivalent.

* Sum of estimated U.S. use of R-11 and R-12 (Hammitt, 1986).

Table 7. 78% Efficient Small Gas Furnaces
Changes in Sulfur and Nitrogen Dioxide Emissions

SO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	Abated From In-home Combustion (tons)	Net Change U.S. SO_2 Residential (tons)	Percent of Annual Emissions
1995	-1,200	-200	-11	-1,500	-0.9
2000	-3,300	-600	-22	-3,900	-2.4
2005	-4,800	-1,000	-34	-5,800	-3.6
2010	-5,500	-1,300	-46	-6,800	-4.2
2015	-5,300	-1,300	-3	-6,600	-4.1

Cumulative SO_2 reduction, 1993-2015 = 110,000 tons.

NO_2

Year	Abated From Coal Generation (tons)	Abated From Gas & Oil Generation (tons)	Abated From In-home Combustion (tons)	Net Change U.S. NO_2 Residential (tons)	Percent of Annual Emissions
1995	-600	-200	-92	-900	-0.2
2000	-1,600	-600	-217	-2,400	-0.6
2005	-2,600	-1,100	-409	-4,100	-1.0
2010	-3,200	-1,300	-648	-5,100	-1.3
2015	-3,500	-1,400	-894	-5,800	-1.5

Cumulative NO_2 reduction, 1993-2015 = 80,000 tons.

Table 8. 78% AFUE Small Gas Furnaces
Changes in Carbon Dioxide Emissions

CO_2

Thousands of Tons of Carbon

Year	Abated From Coal Generation	Abated From Gas Generation	Abated From Oil Generation	Net Change	Percent of 1985 World Emissions
1995	-41	-35	-10	-87	-0.001
2000	-119	-92	-27	-238	-0.004
2005	-203	-166	-46	-415	-0.007
2010	-265	-244	-60	-569	-0.010
2015	-292	-317	-71	-680	-0.012

Cumulative CO_2 reduction, 1993-2015 = 8.5 million tons of carbon.

Appendix A. Estimated Dimensions of Foamed Areas in Refrigerator-Freezers and Freezers							
Foamed Area	Dimension	Product Class*					
		A	B	C	D	E	F
		Measurement in inches					
Refrigerator Door	height	39.5	36	38	60.5	-	-
	width	24	28	28	20	-	-
Freezer Door	height	11	19	16	60.5	16	28
	width	24	28	28	12	28	36
Refrigerator Cabinet	height	38	35	40	58.5	-	-
	width	22	26	30	20	-	-
	depth	26	23	24	24	-	-
Freezer Cabinet	height	12	19	18	58.5	55	32
	width	22	26	30	12	26	24
	depth	26	23	24	24	21	26

* Product Class

A: Manual Defrost

B: Partially Automatic Defrost

C: Top Mounted Freezer, Automatic Defrost
Top Mounted Freezer, Automatic Defrost, Through-the-Door Ice
Bottom Mounted Freezer, Automatic Defrost

D: Side-by-Side Refrigerator-Freezers
Side-by-Side Refrigerator-Freezers, Through-the-Door Ice

E: Upright Freezer, Manual Defrost
Upright Freezer, Automatic Defrost

F: Chest Freezer