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Summary of Seven Economic Return-on-Investment Impact Evaluation Studies across Five Offices within the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy

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Introduction

The U.S. Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy (EERE) is committed to ensuring its investments in research and development (R&D) yield positive results for consumers and the economy. As part of this commitment, EERE has funded several independent evaluators to perform retrospective impact studies of its R&D investments to determine the degree to which EERE funding had measurable and attributable effects relative to what might have occurred absent EERE R&D funding. One measure of R&D performance is economic return-on-investment (ROI), measured primarily as benefits-to-cost ratios and net present values. Third-party, peer-reviewed evaluation studies have found that public funding for EERE-sponsored R&D has resulted in sizable, positive economic benefits for the United States.

Since 2010, EERE has commissioned seven impact evaluation studies covering technology innovations across five of its technology offices. These studies quantify the economic ROI that has resulted from EERE investments in energy efficiency and renewable energy R&D. Independent evaluators used rigorous counterfactual analysis methods to help address the following questions:

- To what extent were the deployment and associated economic benefits for new energy efficiency and renewable energy technologies accelerated and attributable to EERE programs?
- How did estimated nationwide economic benefits associated with the deployment of new technologies compare to the costs of the R&D programs?

To answer these questions, independent professional evaluators and economists developed a peer-reviewed R&D evaluation method used to determine the net "realized" economic benefits and costs, and energy and environmental impacts of the EERE R&D investments[1].

1 Evaluating Realized Impacts of DOE/EERE R&D Programs, Rosalie Ruegg (TIA Consulting Inc.), Alan C. O'Connor (RTI International), and Ross J. Loomis (RTI International), August 2014, https://energy.gov/sites/prod/files/2015/05/f22/evaluating_realized_rd_mpacts_9 -22-14.pdf. This method guide is also in the process of being updated and is planned for re-release in calendar year 2025.

R&D investments included in the available studies

To date, evaluators have used this methodology in seven EERE R&D evaluation studies. Table 1 below lists the EERE R&D areas and specific technologies covered in those studies.

As described in the EERE R&D ROI method guide, "a portfolio for the purpose of evaluation studies may be defined as an entire office, an program within an office, a group of programs, or other meaningful grouping of projects or technologies." For some EERE offices, the R&D ROI assessment (also referred to as "social rate of return" in several of the studies) was performed for a subset of its total R&D investments, rather than the entire office. For example, for the EERE Solar Energy Technologies Office, only the R&D programs for solar photovoltaic modules and technology infrastructure supporting solar modules were selected as the portfolio for evaluation. For the Vehicles Technologies Office, the Advanced Combustion Research program's investments into combustion modeling software and laser diagnostics and optical engine technologies for heavy-duty diesel engines were the focus. Other clusters of research in the Advanced Combustion Research program were not included in the evaluation, e.g., combustion and emission control technologies and solid state energy conversion.

Assessing select portfolios and technologies was necessary because retrospective assessments are generally costly and difficult to perform, and there are data constraints in collecting historical information for all programs within an R&D office. The R&D portfolios which were selected for evaluation represented those which appeared to have significant, measurable successes and for which adequate data was available. The evaluation approaches used for these studies calculated the economic benefits only for the selected technologies evaluated and compared those benefits to the total cost of R&D in the respective portfolios, even if all potential technologies receiving research support and any associated benefits were not assessed. The economic estimates resulting from the ROI studies were, therefore, conservative, lower-bound estimates of ROI for those respective portfolios because many R&D investment benefits were not evaluated and assumed to be zero for the purposes of the evaluations. Benefits and costs of other parts of EERE's research portfolio were not assessed.

Table 1. EERE Technology Offices, Portfolios, and Technologies with Completed Economic Return on Investment Studies[2]

EERE Technology Office	R&D Portfolios within the Office	Technologies within Each Portfolio Selected for Detailed Analysis within the Evaluation	Year Study Completed	R&D Performance Period Evaluated	Effective Useful Life (EUL)[3]
Wind Energy Technologies Office (WETO)	Entire WETO R&D portfolio (whole Office)	• Wind turbulence models • Experiments to acquire accurate aerodynamic and structural measurements • Turbine blade material characterization • Wind turbine component demonstrations	2020	1976-2017	Included. EUL out to 2042
Building Technologies Office (BTO)	Residential Building Integration R&D	• Air Tightness • Duct Tightness • Envelope Insulation • Thermal Bridging	2018	1994-2015	Included. EUL out to 2039
Building Technologies Office (BTO)	Emerging Technologies R&D program	Technologies in BTO's HVAC, water heating, and appliance technology portfolio • Flame-retention-head oil burners • advanced refrigeration • heat pump design model and alternative refrigerants	2017	1976-2015	Included. EUL out to 2029
Vehicle Technologies Office (VTO)	Battery Technology for Hybrid / Electric Vehicles	Lithium-ion (Li-ion) and Nickel Metal Hydride (NiMH) battery technologies for electric and hybrid passenger cars and light trucks	2013	1976-2012	Included. EUL out to 2022

2 The reference section of this paper provides the evaluation study citations.

3 As described in the R&D ROI method guide referenced in footnote 1, "Effective useful life is the period over which an asset, such as plant, equipment, and systems and components, with normal maintenance and repair, can be expected to continue to be usable for the intended purpose." For instance, a newly purchased electric vehicle in 2012 is expected to have a useful life of at least 10 years with energy savings benefits accruing out to 2022. A wind R&D ROI study notes that "a 20-year project life is assumed for projects installed in 2012 and before, with EUL increasing by 1 additional year each year until a 25-year project life is assumed in 2017, based on industry trend data."

Table 1. Continued

EERE Technology Office	R&D Portfolios within the Office	Technologies within Each Portfolio Selected for Detailed Analysis within the Evaluation	Year Study Completed	R&D Performance Period Evaluated	Effective Useful Life (EUL)
Solar Energy Technologies Office (SETO)	Solar Photovoltaic Energy R&D Program	Solar PV modules and technology infrastructure R&D supporting Solar PV modules under the following initiatives: • Flat-Plate Solar Array project • Solar PV Manufacturing Technology Project • Thin-Film PV Partnerships	2010	1976-2008	EUL not considered in analysis
Vehicle Technologies Office (VTO)	Advanced Combustion Engine R&D Program	• Laser diagnostic and optical engine technologies focused on heavy-duty diesel engines • Combustion modeling that simulates the fluid dynamics of combustion processes in internal combustion engines	2010	1986-2008	EUL not considered in analysis
Geothermal Technologies Office (GTO)	Entire GTO R&D program (whole office)	• Polycrystalline diamond compact (PDC) drill bits • Binary cycle power plant technology • TOUGH series of reservoir models • High-temperature geothermal well cements	2010	1976-2008	EUL not considered in analysis

Table 2. Reported and 2024 Inflation-adjusted Program Investment Costs and Gross Economic Benefits (not discounted)

Evaluation	Year that Dollars were Inflation-adjusted to in study	Program Investment Costs (millions, as reported for inflation-adjusted year used in the study, not discounted)	Program Investment Costs (millions, inflation-adjusted to 2024, not discounted)	Total Gross Economic Benefit (millions, as reported for inflation-adjusted year used in the study, not discounted)	Total Gross Economic Benefit (millions, inflation-adjusted to 2024, not discounted)
SETO 2010	2008	$3,710.0	$5,420.8	$18,735.0	$27,374.0
GTO 2010	2008	$143.6	$209.8	$39,528.8	$57,757.0
VTO 2010	2008	$931.0	$1,360.3	$70,200.0	$102,571.8
VTO 2013	2012	$971.0	$1,321.2	$3,433.0	$4,671.2
BTO 2017	2015	$743.4	$981.1	$222,419.0	$293,520.5
BTO 2018	2015	$369.0	$487.0	$3,180.0	$4,196.5
WETO 2020	2017	$3,000.0	$3,810.1	$116,600.0	$148,087.0
	Sum Totals	$9,868.0	$13,590.3	$474,095.8	$638,178.0

Table 3. Inflation-adjusted Undiscounted Net Economic Benefits, with Net Present Values and Cost-to-Benefit Ratios at 3% and 7% Discount Rates

Evaluation	Program Investment Costs (millions, inflation-adjusted to 2024, not discounted)	Total Gross Economic Benefit (millions, inflation-adjusted to 2024, not discounted)	Total Net Economic Benefit (millions, inflation-adjusted to 2024, not discounted)	Net Present Value @ 3% Discount rate (millions, inflation-adjusted to 2024)	Net Present Value @ 7% Discount rate (millions, inflation-adjusted to 2024)	Benefit-to-Cost Ratio @ 3% Discount rate (as reported in individual studies)	Benefit-to-Cost Ratio @ 7% Discount rate (as reported in individual studies)
SETO 2010	$5,420.8	$27,374.0	$21,953.2	$8,364.5	$2,131.6	3.2-to-1	1.8-to-1
GTO 2010	$209.8	$57,757.0	$57,547.2	$27,695.8	$11,709.5	197-to-1	126-to-1
VTO 2010	$1,360.3	$102,571.8	$101,211.5	$62,244.2	$33,752.2	66-to-1	53-to-1
VTO 2013	$1,321.2	$4,671.2	$3,350.0	$1,772.9	$688.5	2.8-to-1	2-to-1
BTO 2017	$981.1	$293,520.5	$292,539.5	$106,468.8	$32,333.3	164-to-1	74-to-1
BTO 2018	$487.0	$4,196.5	$3,709.5	$2,083.7	$940.9	7.2-to-1	5.4-to-1
WETO 2020	$3,810.1	$148,087.0	$144,276.9	$39,879.4	$8,128.3	18-to-1	6-to-1
Totals	**$13,590.3**	**$638,178.0**	**$624,587.7**	**$248,509.3**	**$89,648.3**	**N/A**	**N/A**

Aggregate economic performance results

EERE's cumulative Congressional appropriations and associated R&D investments from 1976 to 2017 were approximately $59 billion in 2024 inflation-adjusted dollars.[4] Table 2 above summarizes the combined total portfolio investment costs which were included in the seven evaluation studies of $13.59 billion (2024$) over the1976-2017 period. For any given study, the EERE R&D ROI methodology computed economic returns by comparing the combined monetary value of energy and human health benefits of select technologies in a portfolio against total portfolio investment cost. This roughly $14 billion represents roughly 24% of EERE's total $59 billion cumulative R&D investment from 1976 to 2017.

Each of these seven independent studies quantifies the economic performance results of EERE's R&D investments for its respective portfolio research areas and technologies, using measures such as net economic benefits[5], benefit-to-cost ratio (BCR)[6], and internal rate of return (IRR).[7] Table 3 above provides aggregate results for these measures. The analysis combined the individual economic benefit and cost cash flows derived from each study to develop the aggregate benefit and cost cash flows from which net economic benefits (net present value) and BCR are calculated. Each of the studies also included discounted cash flow analysis at 3% and 7% discount rates to take into account the time value of money.[8]

A total taxpayer investment of almost $14 billion in EERE's R&D portfolios yielded more than $624 billion in net economic benefits (both numbers in 2024 inflation-adjusted dollars, not discounted). Even with a conservative discount rate of 7%, the net present value of benefits was calculated to be more than $89 billion, significantly greater than all R&D funding expended by EERE over the time periods of these seven evaluations.

Notes about Economic results

The economic performance results in Table 3 above may be considered conservative for several reasons.

- *Effective Useful Life (EUL) was not considered in three of the studies.* The three 2010 economic studies listed in Table 1 only included energy savings and monetized human health benefits accrued through the R&D investment period up to 2008. They did not estimate EUL future savings that would occur for already installed technologies for the remainder of their useful life. Any additional economic benefits that have accrued since 2008 from the technologies in these three studies, or that will continue to accrue during the useful life of the installed systems, have not been counted in the calculated net economic benefits.
- Only a small fraction of EERE R&D and technologies were evaluated to determine return on investment, and many positive returns have yet to be evaluated. The seven studies performed involved in-depth economic assessments for fewer than two dozen R&D innovations and energy technologies that were supported by EERE funding and subsequently commercialized. Full counterfactual economic analysis has yet to be performed over the R&D investment periods for hundreds of other EERE R&D and technology areas, such as lighting (e.g., light-emitting diodes), advanced manufacturing, and vehicle lightweighting, among others. In fact, a recent study has documented examples of many hundreds of commercial technologies enabled by EERE-funded

4 Source: EERE Past and Present Budgets (Congressional Budgets and Budget-in-Brief Materials), https://www.energy.gov/eere/past-and-present-eere-budget

5 Gross economic benefits are based on calculated realized energy cost savings and health benefits (avoided adverse health incidents due to reduced air pollution as determined by the EPA CO-Benefits Risk Assessment (COBRA) model). Net economic benefits = gross economic benefits less EERE investment costs.

6 Benefit-to-cost ratio = ratio formed by setting the numerator as the summation of monetized benefits resulting from EERE's investments, and the denominator as the value of EERE investment costs.

7 Rate of return is the percentage yield on an investment.

8 OMB guidance for benefit-cost analysis of Federal programs using real social discount rates was released in 2023 and recommended a single, 2% real discount rate. These older studies assessed both undiscounted values, values discounted at a 3% rate, and 7% rate, and all of those are reported to demonstrate the range into which the recommended 2% assessment value would fall. Circular A-4 and Circular A-94: https://www.whitehouse.gov/wp- content/uploads/2023/11/CircularA-94AppendixD.pdf and https://www.whitehouse.gov/wp-content/uploads/2023/11/CircularA-4.pdf.

R&D[9]. The ROI for the commercialized technologies identified in that study would likely be significant.

- *Not all benefits associated with the selected R&D portfolios and their technologies are valued in monetary terms.* Benefits from avoiding environmental effects from land and water pollution, energy security impacts, and knowledge spillover impacts were not estimated in monetary terms.

Without having performed an evaluation of all EERE portfolios and supported technologies, it is not possible to know the full extent of EERE's return on investment. It is likely there are significant additional economic benefits attributable to EERE that are not known and may never be quantified. Even if the EERE investments not covered in the seven studies generated zero benefits, the net benefits from the several dozen technologies evaluated to date would still far outweigh the total taxpayer investment in the EERE portfolio, with large and positive benefit-to-cost ratios. As previously noted, the economic results summarized must be considered lower-bound, conservative estimates.

Conclusions

Since 2010, seven EERE economic ROI evaluation studies across five EERE Offices have been completed that examined a variety of research areas and nearly two dozen technologies covering an overall investment period 1976-2017 (not all studies covered that entire time period). The combined results show that EERE R&D investments representing approximately one-fourth of the organization's Congressionally appropriated budgets during the study period (roughly $14 billion out of a historical total of $59 billion, in 2024-adjusted dollars), resulted in a positive return of more than $624 billion in net, undiscounted economic benefits, and a net present value (at a 7% discount rate) showing more than $89 billion in benefits (in 2024 inflation-adjusted dollars). These benefits, evaluated for only a handful of successfully commercialized innovations and for only a fraction of EERE's R&D portfolios, are significantly greater than the entirety of EERE's Congressionally appropriated funding during the time periods of study.

These studies indicate that EERE's R&D has yielded measurable, positive economic returns on investment for the U.S. economy. As an organization, EERE is committed to conducting independent, transparent, and methodologically rigorous evaluations of its work, and will continue to improve its efforts to conduct other studies and generate publicly available evidence in the future.

9 An Investigation of Innovative Energy Technologies Entering the Market between 2009 - 2015, Enabled by EERE-funded R&D, 2021

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