Historical Tracking of DOE Technologies, Market Transformation, Deployment, and Codes and Standards for Building Programs: A Decade of Accomplishments, 1990-2000

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Abstract

This study was conducted by Pacific Northwest National Laboratory[1] (PNNL) for the Office of Energy Efficiency and Renewable Energy (EERE) within the U.S. Department of Energy (DOE). The goal of this study is to identify, compare and contrast, and summarize the results of selected previous studies which quantified the energy and some environmental benefits of research and development (R&D), market transformation, development and deployment, and codes and standards programs from 1990-2000. These programs were funded and managed by the former Office of Building Technology, State and Community Programs (BTS) within EERE. The range of benefits resulting from the overall (former) BTS program portfolio ranged from $24 to $44 billion over this ten-year period. These economic benefits represent the gross value of energy cost savings and do not include the incremental technology cost nor the DOE program cost.

The benefit-cost ratio[2] varied among the sub-programs and projects reviewed in this paper. As an example, these ranged from 1.06 to 1.79 for the Weatherization program (deployment) to ~ 3.53 for appliance standards. The benefit-cost ratio for the R&D programs, as a whole, exceeds all other program as the benefits spill over to the other sectors of the economy (a precise estimate is not available due to lack of data on the incremental costs of R&D technologies). Data on market transformation programs are scarce; however the accumulative energy cost savings (not net of incremental investment costs) from DOE Energy Star appliances are estimated to be more than $640 million from 1993-2000.

Introduction

Pacific Northwest National Laboratory (PNNL) assembled and reviewed, and in some cases conducted original assessments of the energy savings, economic benefits (energy cost savings), and pollution prevention gains from a broad range of U.S. Department of Energy (DOE) building projects from 1990-2000. These projects were funded and managed by the former Office of Building Technology, State and Community Programs (BTS) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE). Many of these projects continue, though with different technological and market targets, under the two successor program offices: Building Technologies Program (BT) and Weatherization and Intergovernmental Programs (WIP). This paper will use the BT/WIP naming convention in referring to this combined set of programs. Within EERE, the word "program" is used to describe the eleven programmatic offices within EERE; all activities that occur within these programs are referred to by

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[2] The benefit-cost ratio is estimated as the division of the discounted energy bill savings by the discounted incremental cost in 1995 prices.

DOE as "projects." Because similar activities in the private sector are usually referred to as "programs," the remainder of this paper will use the word "program" instead of "project."

In partnership with industry and government, the BT and WIP programs develop, transform, and deploy energy technologies and practices to make buildings more energy efficient, affordable, and healthier places to work and live. This is accomplished through an array of activities and innovative projects and products. These activities and products, when introduced and accepted in the marketplace reduce energy use, thereby saving billions of dollars in energy costs.

Background

Previous studies of historical BT/WIP program energy savings have either been focused at a single sub-program (e.g., Appliance Standards) focusing on a specific technology or group of technologies, or have been conducted at a higher, program level, but still only including relatively small sample of the total effort in buildings. Our analysis represents a more systematic effort to include the breadth of activities conducted in EERE for the buildings market place using a standard reporting format. While our analysis is derivative and depends highly on the quality and comprehensiveness of other studies, the value represented here is to have all of this information consolidated into a single, consistent format.

In one past evaluation of EERE programs, the National Research Council, in the report, "Energy Research at DOE: Was it Worth it?" noted that:

> "The committee also found that DOE has not employed a consistent methodology for estimating and evaluating the benefits from its RD&D programs in these (and, presumably, in other) areas. Importantly, DOE's evaluations tend to focus on economic benefits from the deployment of technologies, rather than taking into account the broader array of benefits (realized and otherwise) flowing from these investments of public funds." (NRC 2001, 5)

Our analysis is intended in some part to address these shortcomings. Our evaluation focuses on the four primary strategic approaches of the BT and WIP programs:

- Technology research and development (R&D)
- Codes and standards
- Market transformation
- Community development and deployment

This paper is organized in this manner so as to group similar programs (and results) together in order to avoid comparisons of programs which are disparate in nature.

Objectives

The objectives of the analysis are to identify and quantify the energy and some environmental benefits of a large number of BT/WIP programs. Specific objectives are listed below:

1. Quantify the energy savings from the selected BT/WIP programs in the residential and commercial sectors from 1990-2000.
2. Quantify the monetary benefits of the selected programs to consumers and producers.
3. Calculate the net benefits of the selected programs.
4. Assess the environmental impact of the selected programs (e.g., CO_2 emissions reductions).

Approach

PNNL surveyed a wide range of studies that have evaluated the impact of programs funded by BT/WIP and investigated the methodology used in each. The results of previous studies were not re-validated, but an attempt was made to present the results of these studies in a consistent manner. In this study, PNNL aggregates the energy, energy-cost savings, and environmental benefits into the four strategic approaches employed by BT/WIP. These estimates are in turn used to calculate rates of returns on investment for the four strategic approaches.

Results

BT/WIP Program Overview

The enacted budget for the selected BT/WIP programs in FY 2000 was about $284 million compared with $216 million in 1996 (or approximately $231 million in 2000 $)[3] (EERE 1996; EERE 2000). During the period 1993-2000, the enacted budget for BT/WIP in total was $2.24 billion (2000 $) (EERE 1994, 1995, 1996, 1997, 1998, 1999, 2000). This budget was distributed among a wide range of programs and activities, from R&D to deployment. One of the purposes of this study is to tie the costs of specific activities, or groups of activities, to the historical benefits.

For example, in FY 2000, the program receiving the most funding in BT/WIP was the Weatherization Assistance Program. Weatherization received about half of the budget, while building research and standards received the next largest share of 26.6%. The State Energy Program and community development received 11.8% and 6.4% of the budget, respectively, and the rest of the budget was allocated to smaller programs such as Energy Star appliances and the Energy Efficiency Science Initiative (see Figure 1).

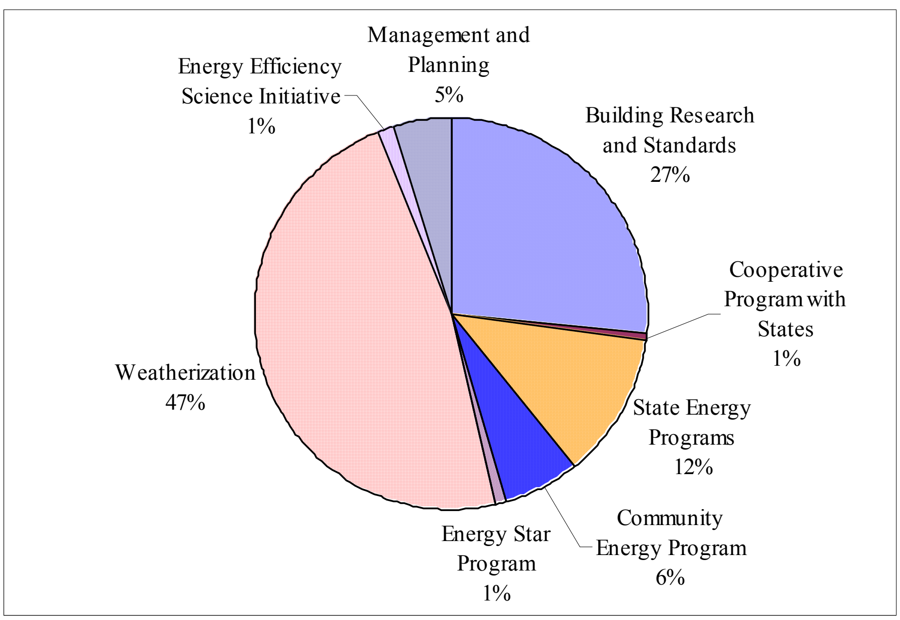

Figure 1. BT/WIP Program Funding Profile – FY 2000 (source: EERE 1999)

[3] Calculated based on the implicit price deflators for gross domestic product, Table 7.1, BEA 2003.

Research and Development

Generally speaking, compared with other strategies, investment in R&D has a longer-term impact and a longer time span between the investment and resulting benefits. Figure 2 shows the accumulated benefits in terms of energy cost savings for several major building technologies developed by the BT/WIP programs. The accumulated benefits from each technology differ broadly and are driven by such factors as year of commercialization, size of target market, and increase in efficiency versus the displaced product. For example, considering the products in Figure 2 only, accumulated energy cost savings from the building technology R&D products exceeded $27 billion from their inception (mostly late 1970s) to the year 1995 (Office of Science Policy 1995).

The benefits from these R&D programs can be relatively large. Overall, the range of benefits resulting from the R&D programs during the last three decades varies between less than $1 billion to about $9 billion in accumulative benefits with a cumulative total of nearly $30B in energy cost savings (see Figure 2). At the lower end, it is estimated that R&D in fluorescent lamp ballasts has improved lighting quality and saved consumers $750 million in energy costs from 1986 to 1997 (Office of Science Policy 1995). As another example, the NRC study, estimated the net realized economic benefits for the flame retention head oil burner were $7.5 billion using a simplifying assumption that the private sector would have introduced these technologies five years later without government sponsored R&D (NRC 2001). Because it is difficult to reconstruct funding histories for specific technologies, benefit-cost ratios for the R&D programs cannot be calculated individually, however a visual inspection of the benefits versus the total funding spent on R&D indicates that those ratios would be significant.

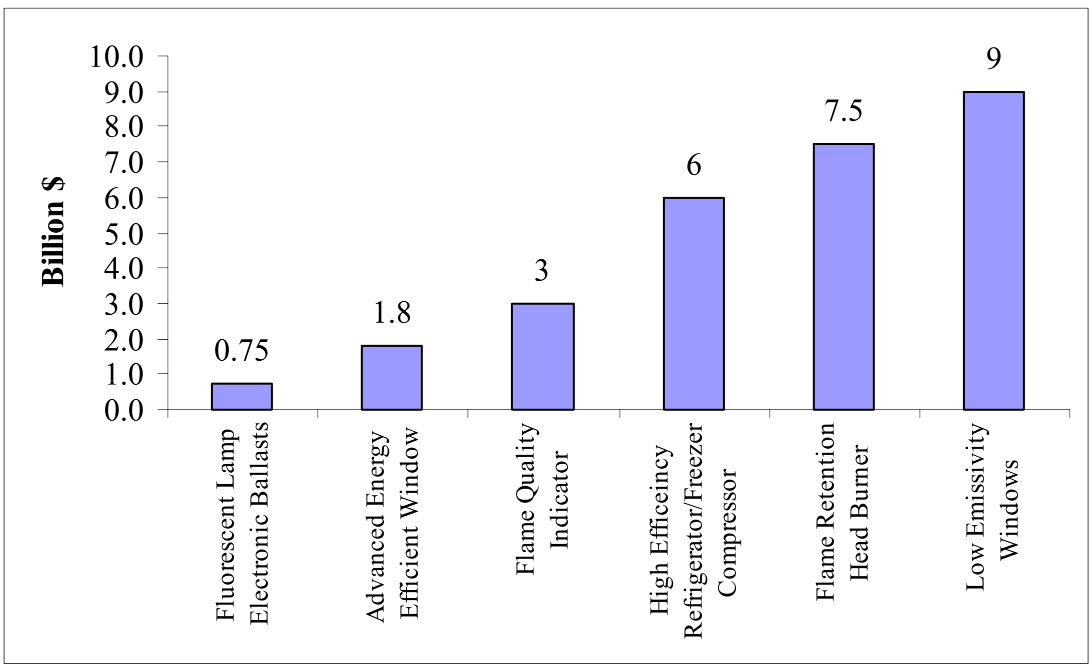

Figure 2. Energy Cost Savings Due to Selected Energy R&D from Project Inception to 1995 (sources: Office of Science Policy 1995; Garland & Garland 1997; and NRC 2001)

Deployment

Building deployment programs vary in both their approach and target markets. Deployment programs are currently in the purview of the Office of Weatherization and Intergovernmental Programs (WIP). The Weatherization Assistance Program is the largest deployment program in WIP in terms of funding. The Weatherization program, in partnership with the States, provides funding to local organizations that in turn retrofit existing homes occupied by low-income families. Oak Ridge National Laboratory (Berry et al. 1997) reported a 23.4% reduction in consumption of natural gas, the predominant home heating fuel within the households weatherized, for all end uses compared with a 13.5% reduction reported by an earlier ORNL national evaluation study. With the increased energy savings, the value of annual avoided energy costs per gas-heated household also increased from an average of $101 to $182, and the benefit/cost ratio for the program rose from 1.61 to 2.40. In another study of the program's economic benefits, an estimated average lifetime savings of $1,123 were realized per weatherized home (Schweitzer & Berry 1999). Considering that five million homes have already been weatherized, economic benefits have most likely exceeded $5.5 billion.

Three different studies evaluated the energy, installation and societal benefit-cost ratios due to the Weatherization project (Berry et al. 1997; Schweitzer & Berry 1999). The ratios were examined from three perspectives: program, where the only benefit valued was net energy savings, and costs included installation, management, and overhead; installation, where the only benefit valued was net energy savings, and the only costs included were installation expenditures; and societal, where benefits included both net energy and non-energy benefits, and costs included installation, management, and overhead. The benefit-cost ratio of the overall program perspective varies within the range of 1.06 to 1.79. The installation benefit-cost ratio showed a larger range among the three studies (1.58 to 2.02). The societal perspective showed a benefit-cost ratio range of 1.61 to 2.12 (see Table 1).

Table 1. Benefit-Cost Ratios for National and Metaevaluation Studies

Study	Program Perspective	Installation Perspective	Societal Perspective
1989 National Evaluation (Berry et al. 1997)	1.06	1.58	1.61
1994 Metaevaluation (Berry et al. 1997)	1.79	2.39	2.40
1999 Metaevaluation (Schweitzer & Berry 1999)	1.51	2.02	2.12

Schweitzer and Tonn (2002) estimated other non-energy benefits from the Weatherization assistance project and had broken these non-energy benefits into three major categories: (1) ratepayers benefits (such as rate subsidies avoided, lower bad debt write-off, reduced carrying cost on arrearages, fewer notices and customer calls, and fewer shut-offs and reconnections), (2) household benefits (such as water and sewer savings, property value benefits, reduced mobility reduced transaction cost , fewer fires and illness and improved comfort), and (3) societal benefits (such as reduction in pollutants and wastes, beside fish impingement, as well as avoided unemployment benefits) (see Table 2).

Table 2. Point Estimate of the Average Lifetime Monetary Value per Weatherized Home

Type of Benefits	Point Estimate (2001 $ per Participant Household (NPV)
Ratepayer Benefits	
Payment Related	181
Service Provision	150
Household Benefits	
Affordable Housing	783
Safety, health and comfort	123
Societal Benefits	
Environmental	869
Social	117
Economic	1,123
Total Average Non-energy Benefits	3,346
Total Houses Weatherized ~ 5 million	over $15 Billion Dollars of Non-energy Benefits

Market Transformation

Market transformation programs include labeling, information dissemination, and partnership formation. Each of these activities is meant to provide the information and institutions which will increase the demand for energy-efficient products and services. This set of activities works in concert with research and development to form a bridge between the laboratory developments and the marketplace for energy efficient products. Success for market transformation activities is usually measured by the number of products or buildings being impacted, or the number of end-use consumers being reached.

For example, the Energy Star appliances program generated energy savings of about 480 trillion Btu (TBtu)[4] in the year 2000 (Webber et al. 2002). The accumulative energy cost savings (not net of incremental investment costs) from DOE Energy Star appliances are more than $640 million from 1993-2000 (calculated based on assumptions from Webber et al. 2002).

The Energy Star program generated non-energy benefits including societal and environmental benefits. Carbon savings due to the Energy Star program are estimated to be about 26.9 Metric Tons Carbon (MtC) during the period 1993-2000 (see Table 3).

[4] One trillion Btu (TBtu) equals 10^12 or 1,000,000,000,000 Btu, which is equivalent to 168 thousand barrels of crude oil, 48 thousand short tons of coal (enough to fill a train of railroad cars 4.4 miles long), 974 million cubic feet of natural gas, or 8 million gallons of gasoline (source: EERE 2002, Table 6.1.2)

Table 3. Energy and Non-Energy Benefits due to Energy Star Major Selected Products 1993-2000

Benefits		1993	1994	1995	1996	1997	1998	1999	2000	Cumulative
Energy Savings (QBtu) [5]	Refrigerator	0.001	0.003	0.004	0.006	0.008	0.010	0.012	0.014	0.058
	Clothes Washer	-	-	-	-	0.002	0.005	0.007	0.009	0.023
	Dishwasher	0.001	0.002	0.003	0.004	0.006	0.007	0.009	0.008	0.041
	Room Air-Conditioner		0.001	0.001	0.002	0.003	0.003	0.004	0.004	0.019
Economic Savings (Million 2000 $)	Refrigerator	4.455	9.252	14.087	19.465	25.475	32.471	40.236	48.000	193.440
	Clothes Washer	-	-	-	-	9.697	21.572	34.860	43.000	109.130
	Dishwasher	1.504	3.296	5.205	7.354	9.739	12.431	15.356	14.000	68.885
	Room Air-Conditioner		2.179	4.542	7.482	10.199	13.268	16.960	17.000	71.630
Carbon Emissions Avoided (MtC)	Refrigerator	0.011	0.023	0.035	0.049	0.064	0.081	0.101	0.120	0.484
	Clothes Washer	-	-	-	-	0.025	0.055	0.089	0.110	0.279
	Dishwasher	0.004	0.008	0.013	0.018	0.024	0.030	0.037	0.034	0.167
	Room Air-Conditioner		0.006	0.012	0.019	0.026	0.034	0.044	0.044	0.185

Source: Webber & Brown 1998.

Codes and Standards

BT and WIP have programs in both equipment standards, including lighting and appliances (e.g., refrigerators and air conditioners), as well as building codes (e.g., insulation levels in the attic). In the case of appliance standards, McMahon et al. of Lawrence Berkeley National Laboratory (LBNL) reported that observed impacts over the previous decade were large and significant (McMahon et al. 2000). For example, in 1997 alone, appliance standards were responsible for reducing residential energy consumption by approximately 2.5%, thus saving $3.5 billion in annual energy costs.

Another LBNL study estimated both the historical and prospective impact of the U.S. energy efficiency standards for residential appliances (Meyer et al. 2002). Meyer et al. used subjective estimates of how energy efficiency might have evolved in the absence of standards, using judgment as to technical changes that might have been introduced by manufacturers that would have improved efficiency without standards. Meyer et al. also considered non-regulatory factors that contributed to efficiency increases in the base case, including government and private R&D and utility demand-side programs. The resulting energy savings from appliance standards varied between 3.6 and 4.2 quadrillion Btu (QBtu) because of the different time period and assumptions used in previous studies (see Figure 3). For example, Meyer et al. estimated both realized and prospective impacts of the standards. The retrospective analysis considered the expected impacts from energy efficiency without the standards compared to previous studies which reflect no change in energy efficiency without the standards. To estimate prospective impacts, Meyer developed new projections for product shipments based on recent trends and appliance industry near-term forecasts.

[5] One quadrillion Btu (QBtu) equals 10^15 or 1,000,000,000,000,000 Btu, which is equivalent to 168 million barrels of crude oil (17 days of U.S. imports), 48 million short tons of coal (enough to fill a train of railroad cars 4,450 miles long), 974 billion cubic feet of natural gas, 8 billion gallons of gasoline (22 days of U.S. gasoline use), or 23 hours of world energy use (source: EERE 2002, Table 6.1.2)

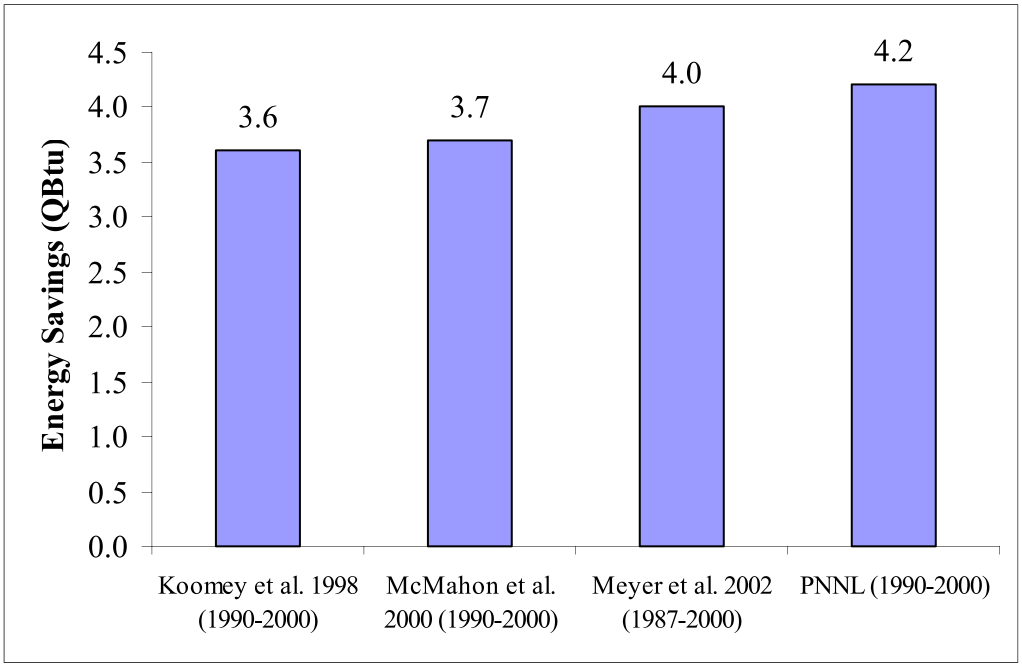

Figure 3. Cumulative Primary Energy Savings from All Appliance Standards

Meyer et al. estimated cumulative net benefits for all products for the period from 1987-2000 from U.S. consumer savings to be $17 billion as of the end of year 2000. Estimated net benefits (net of incremental costs for the more expensive products) from the appliance standards vary among studies because of the differences in the time periods covered and the assumptions employed by the authors. Accumulative net benefits from the appliance standards also vary between $16.6 and $22.9 billion as a result of using different assumptions (see Figure 4). Koomey et al. assumed a 7% discount rate, used 1995 prices, and covered the period 1990-2000. McMahon et al. was adjusted by the incremental cost from Koomey's study and assumed a 7% discount rate, used 2000 prices, and covered the period 1990-2000. Meyer et al. incorporated improvement in energy efficiency without the standard, assumed a 3% discount rate, used 2000 prices, and covered the period 1987-2000. Our analysis was based on the method employed by McMahon, but included additional appliances and assumed a 7% discount rate, used 2000 prices, and covered the period 1990-2000.

Another energy benefit resulting from appliance standards are peak load reductions. Nadel found that in 2000, standards displaced the need for approximately 21 thousand megawatts (MW) of generating capacity, which was about 2.8% of the installed generating capacity in the United States in 2000 (Nadel 2002).

In brief, net energy and economic benefits from the appliance standards are increasing as they reach an average accumulated $20 billion during the decade from 1990-2000. The success of the appliance standards program is due to federal efforts that set minimum energy efficiency standards for classes of products.

The benefit-cost ratio due to the appliances standards is estimated by PNNL to be 3.53 during the period 1990-2000 based on the Koomey et al. 1998 study. However, individual benefit-cost ratios vary between different standards due to the type of fuel targeted, incremental cost of the new appliance meeting the standard level, and the year the standard was enacted. The benefit-cost ratio of standards varies from 0.97 for natural gas clothes dryer standards to 82.7 for the electric clothes washer.

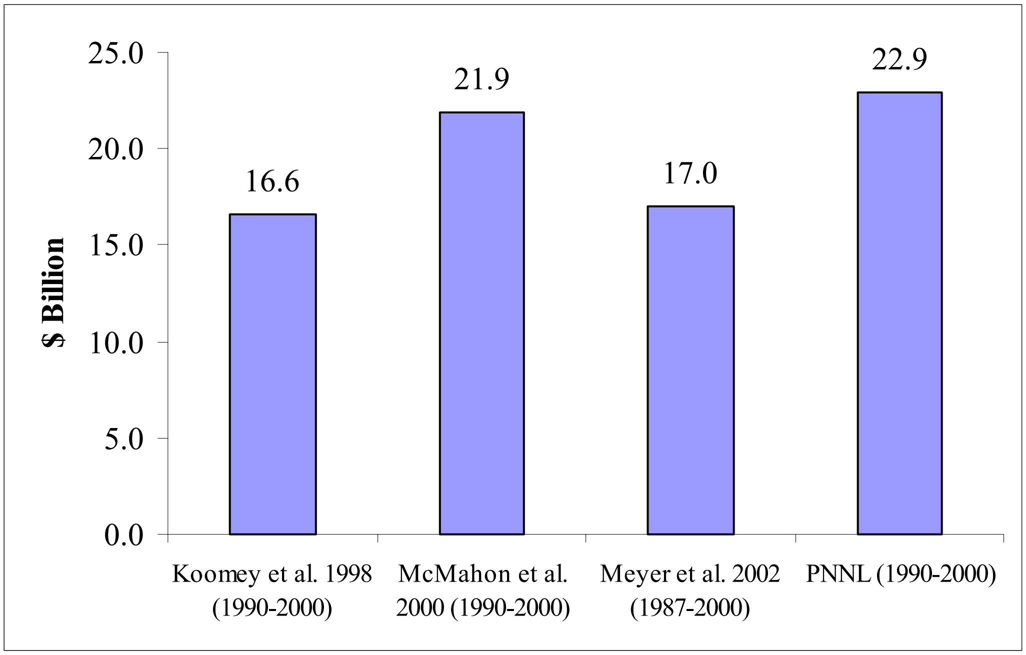

Figure 4. Net Present Value of Energy Savings Benefits from All Appliance Standards

Summary

Aggregating the costs and benefits from the DOE building programs across the four strategies used in this study was difficult because of the wide range of assumptions used between the studies examined. The studies' assumptions varied significantly, including discount rates, fuels considered, prospective versus realized impacts, geographical region, and the time period covered. Table (4) briefly summarizes the ranges of basic assumptions found in previous studies. For example, previous studies used different discount rates to estimate expected cost and benefits the different building programs. Two studies may have used different discount rates to estimate costs and benefits of the same EERE program.

This study attempted to aggregate the results using the minimum possible variation from large array of studies and reports. Because of the wide range of results, we summarized the impact within a range that showed a reasonable maximum between the selected studies, a minimum, and a mid-point representing the best simple average. The drawback of this measure is that it is simplistic and hides many other significant factors.

Table 4. Range of Selected Assumptions Used in Various Studies

Activity	Life (years)	Discount Rate Range (%)	Historical Period Covered
Research and Development	5-30	Undiscounted - 6	1978-2000 and 1980-2000
Market Transformation	10-30	4	1993-2000
Deployment	1-20	3.2-4.7	1989-1996 and point estimates: 1981, 1989, and 2001
Codes and Standards	5-16	7	1990-2000

The accumulative benefits from selected R&D technologies during the last three decades varied from <$1 billion to ~$9 billion with a cumulative total of nearly $30B in energy cost savings. The market transformation and deployment programs had economic benefits from ~$7 to ~$7.5 billion, while the codes and standards program had benefits from ~$16.6 to ~$30 billion. It should be noted that the delineation of economic benefits among these programs is somewhat artificial in that individual technologies developed through R&D often later are featured in deployment and implementation and even in codes and standards. It should also be noted that aggregations from programs with different objectives are somewhat arbitrary and need to be taken very cautiously.

The benefit-cost ratio (the net present value of discounted bill savings divided by incremental cost) varied among the sub-programs and projects reviewed in this paper. For example, the benefit-cost ratios ranged from 1.06 to 1.79 for the Weatherization program (deployment) to ~3.5 for appliance standards. The benefit-cost ratio for the R&D programs, as a whole, exceeds all other programs because the benefits spill over to the other sectors of the economy (a precise estimate is not available because data are lacking on the incremental costs of R&D technologies). Data on market transformation programs are scarce; however the accumulative energy cost savings (not net of incremental investment costs) from DOE Energy Star appliances are estimated to be >$640 million from 1993-2000.

Benefits resulting from the programs covered in this paper varied widely among the different studies in terms of the dollar-value returns to the energy cost savings. Depending on the assumptions, data sources, and methods used for estimation, the estimated energy cost savings (not net of investment cost) across the four strategies vary from $23.7 billion to $43.9 billion for the period 1990-2000.

The need for a guideline to estimate benefits to EERE programs is crucial for obtaining realistic and robust evaluation estimates. The guideline is important for constructing basic assumptions that the evaluation society participants can agree on. At the 2003 conference on estimating benefits of government-sponsored energy R&D, participants suggested a refinement of the NRC benefits framework to allow for a broader array of possible impacts (Lee et al. 2003). Conference participants also issued a number of resolutions on issues such as the treatment of discounting, amortization, marginal pricing, and uncertainty ranges.

In conducting our study, we conclude that a need exists for a set of consistent guidelines for the historical evaluation of EERE programs. Such guidelines should consider at a minimum 1) Using a band, rather than point estimates for benefits by varying key assumptions such as discount rate levels; 2) Adoption of a common time scale for analysis and a more flexible approach than that used by the NRC for the attribution of program benefits as the program approaches (R&D versus deployment) varies significantly, and 3) use of sensitivity analysis of the results to establish confidence intervals for the estimates.

References

Bureau of Economic Analysis (BEA). 2003. National Income and Product Accounts Tables. http://www.bea.doc.gov/bea/dn/nipaweb/. Accessed May 2003.

Berry, L., M.A. Brown, and L.F. Kinney. 1997. *Progress Report of the National Weatherization Assistance Program.* ORNL/CON-450, Oak Ridge National Laboratory

Building Science Corporation. http://www.buildingscience.com/buildingamerica/energystar.htm Appliance Benefits. January 2003.

Office of Science Policy. 1995. *DOE Success Stories: The Energy Mission in the Marketplace.* http://www.nrel.gov/documents/eren/success.html#building-technologies.

Energy Efficiency and Renewable Energy (EERE). 1994. *Department of Energy FY 1995 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 1995. *Department of Energy FY 1996 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 1996. *Department of Energy FY 1997 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 1997. *Department of Energy FY 1998 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 1998. *Department of Energy FY 1999 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 1999. *Department of Energy FY 2000 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 2000. *Department of Energy FY 2001 Congressional Budget Request, Interior and Related Agencies Appropriations: Energy Conservation.* U.S. Department of Energy, Washington, DC.

Energy Efficiency and Renewable Energy (EERE). 2002. *2002 Buildings Energy Databook.* http://buildingsdatabook.eren.doe.gov.

Garland, P.W. and R.W. Garland. 1997. *Research and Energy Efficiency: Selected Success Stories.* Presented at the 1997 National Convention of Society of Women Engineers (SWE), CONF-970684—5, Oak Ridge National Laboratory.

Koomey, J.G., S.A. Mahler, C.A. Webber, and J.E. McMahon. 1998. *Projected Regional Impacts of Appliance Efficiency Standards for the U.S. Residential Sector.* LBNL-39511, Lawrence Berkeley National Laboratory.

Lee, R., G. Jordan, P. Neiby, B. Owens, J. Wolf. 2003. *Estimating the Benefits of Government-Sponsored Energy R&D: Synthesis of Conference Discussions*. Oak Ridge National Laboratory. http://www.esd.ornl.gov/benefits_conference/report.html

McMahon, J.E., P. Chan, and S. Chaitkin. 2000. *Impacts of U.S. Appliance Standards to Date.* LBNL-45825, Lawrence Berkeley National Laboratory.

Meyer, S., J.E. McMahon, M. McNeil, and X. Liu. 2002. *Realized Prospective Impacts of U.S. Energy Efficiency Standards for Residential Appliances.* LBNL-49504, Lawrence Berkeley National Laboratory.

Nadel, Steven. 2002. "Appliance and Equipment Standards." *Annual Review of Energy and Environment.* 27:159-92.

National Research Council (NRC). 2001. *Energy Research at DOE was it Worth it? Energy Efficiency and Fossil Energy Research 1978 to 2000.* National Academy Press, Washington D.C.

Schweitzer, M. and L. Berry. 1999. *Metaevaluation of National Weatherization Assistance Program Based on State Studies, 1996-1998.* ORNL/CON-467, Oak Ridge National Laboratory.

Schweitzer M. and B. Tonn. 2002. *Nonenergy Benefits from The Weatherization Assistance Program: A Summary of Findings from the Recent Literature.* ORNL/CON-484, Oak Ridge National Laboratory.

Webber, C.A., and R.E. Brown. 1998. *Saving Potential of ENERGY STAR Voluntary Labeling Program.* LBNL-41972, Lawrence Berkeley National Laboratory.

Webber, C., R.E. Brown, A. Mahajan, and J. Koomey. 2002. *Saving Estimates of the Energy Star Voluntary Labeling Program 2001 Status Report.* LBNL-48496, Lawrence Berkeley National Laboratory.