Measurement and Baseline Issues Related to Evaluating a Diverse Portfolio of Federally-Supported Building Energy-Saving Projects

Donna J. Hostick, PNNL, Richland, WA
Katherine Allen Cort, PNNL, Richland, WA
David B. Belzer, PNNL, Richland, WA
James A. Dirks, PNNL, Richland, WA
Douglas B. Elliott, PNNL, Portland, OR
David M. Anderson, PNNL, Richland, WA
Jerome P. Dion, DOE EERE, Washington, DC

Abstract

As part of its annual budget request to Congress, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) provides estimates of the expected performance and benefits of the energy-efficiency projects it supports. The authors estimate the energy, environmental, and economic benefits of the projects and technologies that focus on reducing U.S. building energy use. The results of the analysis are used by EERE to estimate future progress towards strategic goals and objectives as well as defend the Presidential Budget before Congress.

This paper focuses on a description and discussion of the methodological approaches used to measure the expected energy benefits produced by a diverse portfolio of building energy conservation projects. This paper also describes the strengths and weaknesses of the modeling approaches and identifies areas that could benefit from additional research. This paper is based on the evaluation of 25 EERE projects that target a mixture of building energy end uses. The types of projects supported by EERE include building and equipment R&D, market transformation, regulatory codes and appliance standards, grant programs, and other deployment activities.

Because of the diversity of types of projects, the overall approach becomes a compromise between the use of a single analytical framework for all projects and one in which tailored methodologies are designed for specific projects.

Introduction

Pacific Northwest National Laboratory[1] (PNNL) estimated the projected energy, environmental, and financial benefits (i.e., metrics) of the technologies and practices funded under the U.S. Department of Energy's (DOE's) Office of Building Technology (BT) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE) for Fiscal Year 2004. EERE revamped an ongoing metrics effort in 1994 to develop more rigorous quantitative measures of project benefits and costs in response to the Government Performance and Results Act (GPRA) of 1993 (GPRA 1993). The supporting analysis and data obtained through the metrics effort are used to estimate future progress towards strategic goals and objectives within BT, to communicate the benefits of EERE projects to DOE and other interested parties, and to defend the budget before Congress. The linking of funding for activities to planned outputs, and to projected outcomes, is a key part of integrating performance and budget under the President's Management Agenda. For Fiscal Year 2004, PNNL based project characterizations on

[1] Pacific Northwest National Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76 RLO1830.

information gathered during interviews conducted throughout the summer of 2001. PNNL reviewed and revised the characterizations during meetings with project managers during the summer of 2002.

Estimating the Energy Savings of BT Projects

Energy savings for the Fiscal Year 2004 GPRA metrics were based on the final 2004 budget request[2]. PNNL estimated the savings of various activities supported by each BT project and then aggregated the savings to the decision unit level (the organizational level at which projects are specifically referenced in budget requests to Congress). PNNL estimated benefits for 25 activities, which rolled up into 13 projects and further into 4 BT decision units (see Table 1).

Table 1. BT Decision Units and Projects Evaluated for Fiscal Year 2004 GPRA Metrics

BT Decision Unit	Projects Aggregated for Fiscal Year 2004 GPRA Metrics	Activities
Residential Buildings	• Residential Technology R&D • Residential Building Codes • Zero Energy Buildings	• Residential Buildings R&D • Residential Building Codes • Zero Energy Buildings
Commercial Buildings Integration	• Commercial Building Technology R&D • Commercial Building Codes	• Commercial Buildings R&D • Commercial Building Codes
Emerging Technologies	• Lighting R&D • Next Generation Lighting • Space Conditioning and Refrigeration R&D • Appliances & Emerging Technologies R&D • Building Envelope R&D: Window Technologies • Building Envelope R&D: Thermal Insulation and Building Materials • Analysis Tools and Design Strategies	• Lighting R&D: Controls • Next Generation Lighting • Space Conditioning R&D: – Residential HVAC Distribution System – Advanced Electric Heat Pump Water Heat – Commercial Refrigeration – Refrigerant Meter • Appliances and Emerging Technologies R&D: – Heat Pump Water Heater – Roof Top Air Conditioning – Gas Condensing Water Heater – Recessed Can Lights – R-Lamps • Building Envelope R&D: – Electrochromic Windows – Superwindows

[2] Estimates are based on Final Budget Request, February, 2003.

BT Decision Unit	Projects Aggregated for Fiscal Year 2004 GPRA Metrics	Activities
		– Quick -Fill Walls – R30/30 Year Roofs – Moisture/Wet Insulation • Analysis Tools and Design Strategies
Equipment Standards and Analysis	• Equipment Standards and Analysis	• Equipment Standards and Analysis: – Residential Gas Furnaces/Boilers – EPAct Standards – Distribution Transformers

PNNL assessed the benefits for a limited number of defined metrics: energy savings, environmental benefits, and economic/financial metrics[3]. For most projects, PNNL segmented the benefits estimates by building sector, building type, region, vintage, end use, fuel type, and type of equipment displaced and aggregated them to obtain the benefits for a project or technology.

In order to develop energy savings estimates, PNNL staff considered project goals, technology characteristics (including performance and cost), the targeted market, and project milestones. The technologies and practices modeled were chosen to represent specific projects. PNNL developed the project characteristics through extensive interaction with the BT office directors and project managers. Because the estimates are produced for the budget request, BT begins planning for the budget process two years in advance.

Most of the BT projects support Research and Development (R&D) of future products and design strategies. The R&D sometimes focuses on developing a technology, such as electrochromic windows, which are not yet available on the market. Other projects support R&D that focuses on modifying an existing technology to improve its marketability. For example, gas condensing water heaters are highly efficient water heaters that are currently available on the market; however, the technology is too expensive to obtain any significant share of market. Thus, the project that supports this technology focuses on significantly reducing component and manufacturing costs.

Methodology

EERE is faced with the difficult challenge of estimating and reporting the expected benefits of a diverse group of projects that include new technologies and practices impacting the transportation, utility, industrial, commercial, residential, and federal sectors. This challenge is compounded by attempting to maintain a link between the estimated savings, the goals outlined in the draft budget request presented to the Office of Management and Budget (OMB), and the Presidential Budget submitted to Congress. The content and level of funding requested for specific activities can change substantially over the course of several months of OMB review and negotiation, sometimes changes can even occur in the final days before release.

[3] The environmental (emissions reductions) and economic benefits (energy cost savings) that are estimated relate directly to projected energy savings. The environmental benefits, for example, relate to the burning of fossil fuels to produce energy (e.g., air pollutants such as CO_2 and SO_2) and do not include measurements of such things as land-use degradation or localized water pollution that may also occur when producing energy.

Because of the diversity of types of projects, the overall approach becomes a compromise between the use of a single analytical framework for all projects and one in which tailored methodologies are designed for specific projects. In the past, both the single-method and multiple-method approaches have been utilized to report a range of estimates for EERE programs.

Single-Method Approach (NEMS-GPRA04)

The single-method approach is based on Energy Information Administration's (EIA's) National Energy Modeling System (NEMS). NEMS is the primary mid-term forecasting tool used for projections contained in EIA's Annual Energy Outlook. NEMS consists of a series of computer simulation models that represent all the major energy supply and demand sectors of the U.S. economy. NEMS represents domestic energy markets by explicitly representing the economic decision making involved in the production, conversion, and consumption of energy products and, where possible, it includes explicit representation of energy technologies and their characteristics.

Each of EERE's eleven program offices develops benefit estimates for projects under their purview. In addition, the programs provide the model inputs (project characterizations) used by EERE analysts in a larger, integrated modeling, effort. The purpose of the integrated analysis is to account for inter- and intra-sector double counting, market trends, and reductions in new electricity generation created by reduced demand. EERE currently uses a modified form of the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), called NEMS-GPRA04.

Where possible, BT projects are modeled in the NEMS-GPRA04 framework. For the BT projects, NEMS-GPRA04 modeling inputs are based on the inputs developed by PNNL for the BT analysis (PNNL 2003). There are some projects, however, that are expected to be more efficient without an increase in the consumer cost. Because NEMS incorporates the tradeoffs between performance and cost within its calculations of market penetration, these types of projects cannot be modeled in NEMS because the zero incremental cost causes an unrealistically high penetration rate to be produced. For these projects, energy savings are estimated off-line and reduced by 30% to be comparable with the overall NEMS-GPRA04 results (EERE 2003)[4]. The 30% figure represents the approximate difference between BT project estimates calculated by PNNL for BT utilizing multiple methods and the NEMS-GPRA04 estimates where projects were modeled solely in NEMS-GPRA04. To incorporate these projects into NEMS-GPRA04 so that they could be included in the integrated analysis, modifications were made to the NEMS-GPRA04 input files, such as changing the consumer hurdle rates for the appropriate end uses or modify the autonomous building shell efficiency indices. These and other parameter changes were adjusted to yield the approximate level of energy savings developed from the off-line analysis.

The advantage of using this single-method approach using the NEMS model is that it provides consistency and integration across the EERE projects, eliminating some of the potential "double-counting," both between and within each of the EERE projects. Additionally, the impacts of changes that affect the entire baseline can be incorporated relatively quickly, allowing for various scenarios to be analyzed (e.g., a dramatic decrease in the supply of oil, causing a significant increase in the forecasted price of oil).

One disadvantage of using a single-method approach is that there are a number of projects or activities that do not easily fit into the model framework. In order to "model" these projects, it becomes necessary to either use a series of inputs that are meant to approximate the project's goals or leave the projects out of the modeling framework altogether. In the latter case, benefits estimates are either

[4] Documentation at the project-level is not currently available for the NEMS-GPRA04 results, thus it is not clear how many projects or activities were modeled using this approach.

adopted wholesale from other sources, or are calculated as some simple share of those projects, that do make their way into the model. While models such as NEMS have been peer-reviewed, the application of NEMS to projects beyond its capabilities may be more difficult to defend, particularly at a lower level of aggregation such as at the technology/activity level (e.g., Advanced Heat Pump Water Heater or Refrigeration Meters) as opposed to a higher project level (e.g., Refrigeration R&D). A single framework sometimes cannot characterize specific projects to a degree required to meet the desired level of rigor.

Multiple-Method Approach (PNNL Approach)

Historically, PNNL's approach to the EERE GPRA process has been to employ multiple estimation methods. As with the single-method approach, the multiple-method approach employs a modified version of NEMS; however, the multiple-method approach also employs other models in order to tailor the estimates to the specific project characteristics, as the projects being modeled are quite different in both approach (Codes and Standards versus R&D) and technologies (computer software versus equipment). PNNL calculated benefits using three methods: (1) PNNL adaptation of NEMS (NEMS-PNNL); (2) PNNL-developed tool, Building Energy Savings Estimation Tool (BESET); and (3) spreadsheets designed for a specific project.

NEMS-PNNL allows the costs and benefit characteristics of a technology and its market penetration to be linked. However, NEMS-PNNL has difficulty representing some BT technologies, such as the projects that go beyond single technologies to the integration of building components as a system (e.g., interaction of natural lighting and artificial lighting). These system integration or "whole buildings" approaches are best dealt with using an analysis tool more in tune with the activities being analyzed.

BESET was built by PNNL in the mid-1990s to specifically estimate the benefits of BT projects. BESET allows a wide variety of projects to be characterized, including projects that target whole-building energy use, envelope improvements, and equipment efficiency. BESET's major disadvantage is that the market penetration rates (i.e., fraction of sales or fraction of installed base) are determined outside the model and therefore are not explicitly linked to the project's cost and benefit characteristics.

PNNL also relied upon individual spreadsheet calculations to model the energy savings of projects not easily modeled in BESET or NEMS-PNNL. In several cases, sub-programs within BT (e.g., Codes and Standards) have made significant investment in developing spreadsheet tools to examine the impact of proposed standards. Rather than duplicate these efforts, PNNL adopted and adapted these spreadsheets to the GPRA analysis and requirements.

An advantage of utilizing a multiple-method approach in estimating benefits for a diverse portfolio is that the chosen method is tailored to the specific characteristics of a project or new technology. By tailoring the approach to the program, rather than trying to modify, approximate, or force inputs into a single universal framework, it is believed that the results better represent the actual program activities. The multiple-method has the additional benefit of increased transparency, as spreadsheets are widely understood while large econometric models have embedded assumptions or are otherwise not readily examinable by most users.

One disadvantage of the multiple-method approach is that it is more difficult to maintain consistency in "baseline" inputs. Baseline inputs, like growth in commercial floor space, and energy prices can be held constant and uniform across many technologies in a large modeling system like NEMS-GPRA04. In addition, these baselines can be varied readily and quickly. With a multiple-method approach, maintaining consistency in the baseline is more difficult due to differences in data requirements. It may also be more difficult to analyze alternative scenarios that involve changing baseline adjustments, as those adjustments may not be easily translated into each method's baseline.

General Methodology Using NEMS-PNNL. Many of the projects in BT's Emerging Technologies and Equipment Standards decision units target specific types of equipment within a building or standards directed toward using specific equipment. Equipment projects are characterized by new equipment efficiencies and are compared with "baseline" efficiencies to calculate energy savings. To determine the penetration of the BT-sponsored equipment relative to the more conventional equipment, a modified version of the NEMS model (NEMS-PNNL) employed for EIA's *Annual Energy Outlook 2001* was used.

NEMS-PNNL selects specific technologies to meet the energy services demands by choosing among a discrete set of technologies that are exogenously characterized by commercial availability, capital costs, operating and maintenance costs, efficiencies, and lifetime. The NEMS-PNNL design can accommodate various technology choices. NEMS-PNNL is coded to allow several possible assumptions to be used about consumer behavior to model this selection process. Projects that target specific building equipment and that have associated cost information can usually be modeled in NEMS-PNNL. These projects are modeled by adjusting the menu of equipment to include relevant BT-sponsored project equipment, technological innovations, and standards. For the Fiscal Year 2004 GPRA metrics, activities or technologies that were modeled in this manner included: Heat Pump Water Heaters, Roof Top Air Conditioners, Gas Condensing Water Heaters, Residential gas furnace/boilers, and the lighting technologies that are included in the Next Generation Lighting project.

For BT projects that target efficiency of the building envelope (or shell), the NEMS-PNNL model was modified to use the shell-efficiency indices (for both residential and commercial buildings) that were developed off-line by PNNL staff. The general approach for envelope (roofs, walls, windows) calculations using NEMS-PNNL was to simulate the effect of an envelope technology using the Facility Energy Decision System (FEDS) model for a number of different building types, sizes, vintages, and locations (PNNL 2002). FEDS is an elaborate building energy simulation tool that permits the estimation of heating and cooling loads for each building with and without the envelope technology being evaluated. The changes in the heating and cooling loads were then used to modify the heating and cooling envelope (or shell) efficiency factors in NEMS-PNNL. These factors were input as a vector for each building type and census region. These vectors captured both the thermal impact and the expected market penetration by year. Market penetration estimates were based on input from the DOE project manager or their representatives. The technologies that were modeled with this approach include all of the Building Envelope R&D activities including: Electrochromic Windows, Superwindows, Quick-Fill Walls, R30/30 Year Roofs, and Moisture/West Insulation.

General Methodology Using BESET. BESET is a bottom-up accounting model that compares baseline energy use against specific EERE-sponsored technologies. BESET also is used to centrally collect, store, and report all results produced by all the various estimation methods. In addition to energy savings forecasts, these results also include such items as associated emissions reductions and necessary investment.

BESET can estimate benefits for various types of projects, including: whole building, envelope, lighting, HVAC, and water heating. Although BESET can model equipment and envelope projects, those projects are primarily estimated using NEMS-PNNL.

To determine energy savings for specific BT projects, BESET requires information in the following areas:

- Project Performance Goals. The goals of each project are assessed in terms of energy savings (e.g., percent load reductions and equipment efficiency improvements) and used as inputs to BESET. PNNL gathers this information from each project by interviewing the project manager or reviewing project literature (e.g., technical reports, brochures, and websites).

- Target Market. Target markets are defined in terms of building sector (e.g., residential and commercial), building type (e.g., residential single-family or commercial office), size (commercial only), income level (residential only), vintage (e.g., new or existing), and climate zone or region.
- Technology Diffusion. Once the target market has been identified, PNNL determines penetration into that market using technology diffusion curves. In 1998, PNNL conducted a study to examine the historical market penetration (i.e., diffusion) for 10 energy-efficient products related to the buildings sector (PNNL 2003). PNNL estimated diffusion models for each product based on the specification proposed by F.M. Bass (1969). PNNL incorporated the diffusion model into the GPRA metrics analysis for many of the projects and technologies not modeled within the NEMS framework. The empirical analysis of market penetration is believed to generate more credible predictions of the adoption process of important energy-efficiency technologies in the buildings sector. The resulting penetration model requires only the year of introduction into the market, an estimate of market penetration in 2020 (provided by BT project managers), and the selection of the most appropriate diffusion curve category (e.g., lighting or HVAC).
- Private Investment (cost). Estimates of private investment for both the baseline and the EERE technology or practice are entered into BESET. Ideally, the investment costs would be a factor influencing market penetration; however, the current diffusion model used does not incorporate costs at this time.

The projects modeled in BESET include activities with the goal of reducing whole-building heating, cooling, and water heat loads (e.g., Residential Buildings R&D, Commercial Buildings R&D, Analysis Tools and Design Strategies, and Residential HVAC Distribution) as well as many of equipment projects that were not easily modeled in NEMS-PNNL, such as the Advanced Electric Heat Pump Water[5], Refrigerant Meter[6], Recessed Can Lights and R-Lamps[7].

Spreadsheet Methodology. Whenever possible, PNNL modeled projects within BESET or NEMS-PNNL to help ensure consistency in baseline inputs and methodology. However, because of their unique characteristics, we modeled several projects in spreadsheets. The estimated savings generated by the spreadsheet models are entered by fuel type into "fixed" tables within BESET so that the environmental and energy cost-savings benefits can be calculated using the same data set as the other projects. We verified the consistency of the baseline assumptions of the spreadsheet tools directly against the EIA data. The activities modeled with individual spreadsheets include the Residential and Commercial Codes projects, Lighting Controls, Commercial Refrigeration, EPAct Standards, and Distribution Transformers.

Baseline Data. To the extent possible, the underlying assumptions about building stock forecasts, equipment efficiencies, market shares, and end-use loads were consistent across tools (i.e., NEMS-PNNL, BESET, and spreadsheets). We accomplished consistency by drawing most of the baseline characterization data from the EIA. For example, the same version of NEMS used to produce EIA's *Annual Energy Outlook* was used in our analysis.

[5] This is a future technology that did not have well enough defined costs to be modeled in NEMS-PNNL.
[6] This technology retrofits existing space conditioning equipment, which cannot be easily modeled in NEMS-PNNL.
[7] The residential lighting choices were not accessible in NEMS-PNNL. Because recessed cans and R-lamps target the residential sector, these activities were modeled using BESET.

BESET also has a baseline characterization, which is drawn from NEMS-PNNL, EIA's *Annual Energy Outlook*, the *Residential Energy Consumption Survey* (RECS 1997), and the *Commercial Buildings Energy Consumption Survey* (CBECS 1995).

The National Research Council Methodology

Each year DOE issues a set of guidelines regarding how the GPRA-Metrics benefits should be estimated, including baseline assumptions. During Fiscal Year 2002, the guidelines for this process were significantly influenced by a National Academy of Sciences report (NRC 2001) that assessed the outcomes of energy efficiency and fossil energy research from 1978 to 2000. One of the report's recommendations for assessing research development and deployment projects was that "DOE should adopt an analytic framework similar to that used by this committee as a uniform methodology for assessing the benefits and costs of its R&D projects. DOE should also use this type of analytic framework in reporting to Congress under GPRA."

As a key assumption in the report, the National Research Council adopted the simplifying assumption that the private sector would have developed the technology in the absence of DOE five years after DOE realized the benefits. This assumption was made in order to more readily compare the impact of the various technologies analyzed, and was not based on empirical evidence or theory that most government efforts merely accelerate introduction of technologies into the marketplace. This assumption was adopted, in part, as part of the uniform process for assessing prospective (future) benefits of EERE projects.

The calculation methodologies for the projects characterized using the National Research Council methodology were modified to remove the estimated benefits that would have occurred in the absence of DOE funding. This change was implemented within the BT estimates by determining the projects that act as acceleration-to-market activities rather than projects that would not have been developed or implemented in the absence of government funding. This approach diminishes the BT project savings in future years, presuming that the private sector is expanding its development and production of these technologies. Figure 1 illustrates how applying this acceleration methodology impacts a project's estimates in its most simplified state.

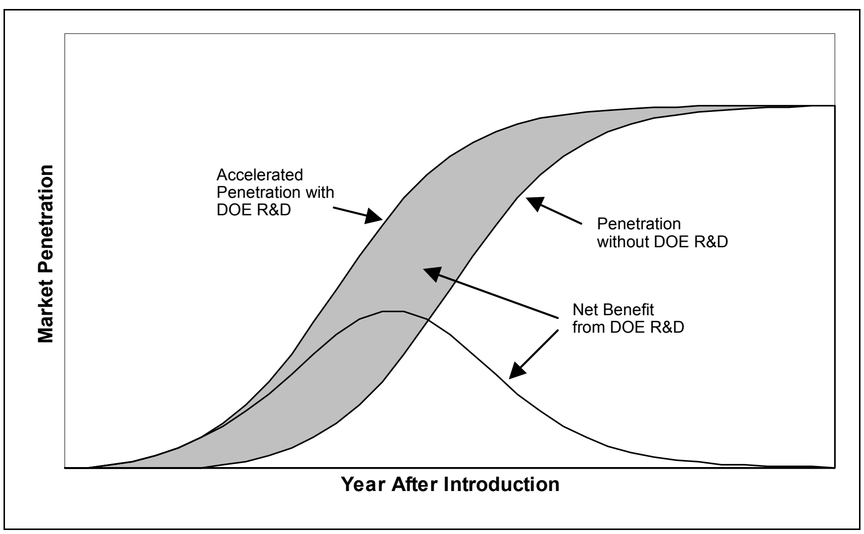

Figure 1. Impact of National Research Council Methodology (pure market acceleration case)

Results

Decision unit benefits for BT are reported annually. The energy savings estimates for 2010 represent energy saved in 2010 only. While these benefits are not cumulative estimates, the energy savings in 2010 are a function of all project activities from Fiscal Year 2004 forward. For example, the energy saved in 2010 from Emerging Technologies activities (e.g., R-lamps, heat pump water heater, etc.) is the energy saved in 2010 only, from all buildings that have installed the technology(ies) between 2004 and 2010. Table 2 summarizes the primary energy savings for the four BT decision units.

Table 2. Primary Energy Savings (TBtu/Year): PNNL Analysis of BT Projects

BT Decision Unit	2004	2005	2010	2020
Residential Buildings Integration	0.6	1.6	18.3	119.4
Commercial Buildings Integration	0.0	0.5	11.8	185.6
Emerging Technologies	19.7	38.2	234.0	901.1
Equipment Standards and Analysis	0.0	3.4	91.4	383.2
Total	20.3	43.7	355.5	1,589.3

Total primary energy savings for all BT projects are estimated to reach 0.36 QBtu[8] by year 2010 and 1.59 QBtu by year 2020 using the multiple-method approach. For comparison, the single-method approach yielded 0.41 QBtu by year 2010 and 1.27 QBtu by year 2020. Figure 2 compares the analysis results between the two approaches: the multiple-method approach employed by PNNL versus the single-method approach represented by NEMS-GPRA04.

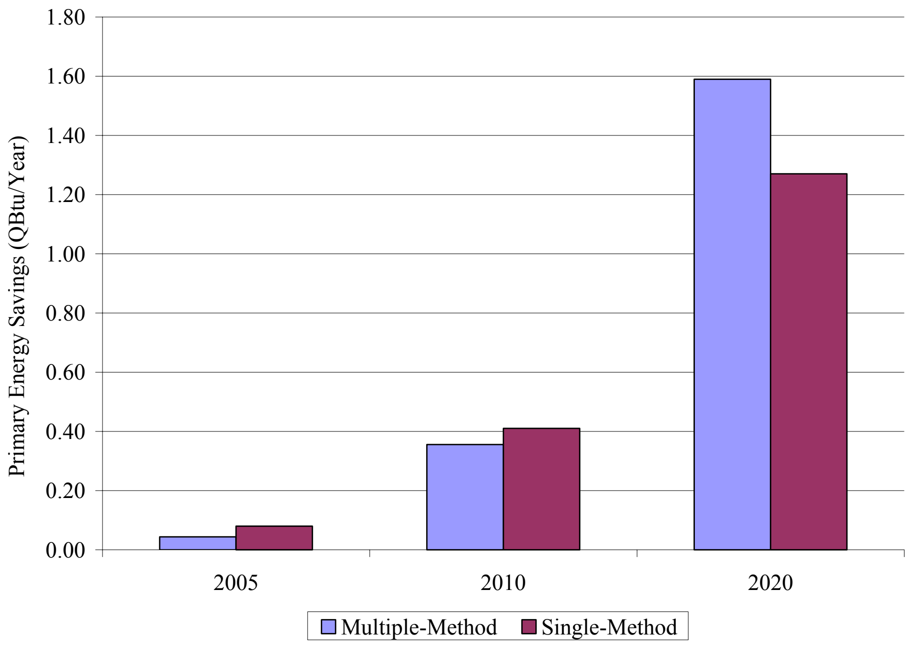

Figure 2. Comparison of Results: Multiple-Method (PNNL) Approach to Single-Method (NEMS-GPRA04) Approach

[8] To provide perspective, primary energy savings in the amount of .36 QBtu and 1.59 QBtu are equivalent to the average annual per capital energy consumption of approximately 1 million people and 4.5 million people in the U.S., respectively (EERE 2002).

The resulting differences between the single-method approach and the multiple-method results are most likely due to the use of the modified NEMS to develop estimates for almost all of the BT projects with the single-method approach. The modified NEMS models base technology choices primarily on measures of cost-effectiveness, which translates into capturing market share in "steps" rather than a more gradual curve. While this approach is comparable with the PNNL procedures for projects modeled in NEMS-PNNL, it would cause NEMS-GPRA04 results to be higher in early years (and potentially lower in later years, as appears to be the case) for those projects that were not modeled in NEMS-PNNL for the PNNL results.

Conclusions and Suggestions for Future Research

Both single model and multiple-method approaches have benefits and drawback. The primary benefit of a single model is consistency in approach, baseline (assumptions), and potential comparability. The biggest single drawback to a single model approach is lack of flexibility to represent the diversity of projects found in EERE. A multiple-method approach is better suited to analyzing such a diversity of projects, but is more complex to use due to the variety of analysis instruments. Secondly, maintaining a consistent baseline is more challenging and scenario analysis an even greater challenge.

When greater consistency is needed across groups of analyses, or when the analyst wishes to integrate results, a single-method may be more favorable because it eliminates the need to develop equivalent baseline comparisons. Single-method approaches also seemingly allow for more transparent comparability between sets of analyses. In situations with limited funding, the results of such analysis are often used to set priorities and rank projects; however, these may be false comparisons given the inability of a single model to adequately represent all projects. Additionally, the use of a single-method approach, particularly when it is possible to account for interactions (as is the case with NEMS), provides more information about the impacts of an entire program, and not just individual projects within a program.

Multiple-method approaches often analyze each project or technology in isolation. Because of the intricacies involved in the interactions between building systems, the resulting impacts on the other systems may not be fully captured. As an example, consider a building that installs more efficient lighting, causing an increase in the heating load, and a reduction in the cooling load (more efficient lighting uses less energy and hence puts less heat into the space). While these interactions may be captured within the individual project estimates, the changes in the base heating and cooling loads are not transferred to other projects, causing a potential overestimation or underestimation of benefits (e.g., an evaluation of a new heating or cooling technology may not assume the lighting is high efficiency).

Suggestions for Further Research

This field would benefit from further research and development of market penetration models (an integral component of all energy projects modeled using BESET), as well as a better understanding of the net impact on the marketplace of government-sponsored R&D. The greatest weakness of current market penetration models is the lack of cost, performance, and sales data available related to future technologies. If DOE is able to determine with a reasonable amount of accuracy the price and performance combination that would enable a given technology to capture some share of the marketplace, then R&D could focus on developing the appropriate balance of efficiency and cost.

R&D is an inherently risky activity. Currently, the GPRA Metrics guidance is to assume 100 percent success in these risky investments. Explicitly incorporating risk into the estimation process would be useful in understanding EERE's program as an investment portfolio, and could lead to sounder portfolio management decisions.

Another potential research involves the NEMS model itself. The NEMS model is updated on nearly an annual cycle. Baseline assumptions change, and often the changes are significant. Understanding the sensitivity of NEMS results to changes in baseline assumptions is important to understanding how the projected benefits of individual projects, and those of the overall portfolio of EERE projects, are impacted by the changing assumptions. In order to increase the transparency of the estimates and to put them in context, it may be useful to indicate that a change in projected benefits for an ongoing program or project is an artifact of the underlying model changes, rather than from a change in the program or project.

Additionally, the accuracy of the NEMS model in projecting the impacts of individual technologies is largely untested. It would be useful to evaluate the accuracy of the model for various forecast periods. If, for example the total energy consumption for a five-year forecast period is shown to be accurate within plus or minus five percent, then how does that translate into the ability to estimate a change resulting from a single project that invests $5 million per year in R&D? Do we understand how accuracy is affected as a factor of length of forecast period? Are the benefits of that single project within the confidence interval of the model's overall results? If we are estimating the impact of a $1 billion portfolio of projects, are those benefits significant when compared to the confidence interval associated with overall model results? If we move individual projects in and out of a $1 billion portfolio, can the model project differences in impact with any statistical significance?

Yet another area of research would be to further delve into the attribution of benefits. The NRC committee focused on the need to identify and quantify benefits directly attributable to government funded R&D. In doing so the committee assumed a blanket (5-year) rule to represent the theoretical actions of private firms in pursuing the same technologies in which the Federal government invested. The blanket rule approach used by the committee could be improved through the development of empirical information demonstrating the validity of this approach, and perhaps establishing a range of assumed private firm behavior. It should be pointed out that the rule used by the NRC represented one view of political economy, and that different rules can be posited based on different views of political economy.

Finally, a greater understanding of the impact of government-sponsored research is needed for DOE planners to appropriately develop program priorities and reduce the potential to "crowd out" private investment. One tendency in government-sponsored research is to focus on incrementally improving the performance of various technologies, which in many cases may be the most appropriate path to improving the technology. It must be recognized, however, that focusing entirely on incremental improvements may inhibit research that could produce revolutionary changes in the market. If, for example, the DOE had focused all of its effort on incrementally improving the efficiency of the incandescent lamp, it might have missed the leap to the Compact Fluorescent Lamp (CFL). Fortunately, EERE recognized this opportunity and DOE-sponsored CFL research has contributed to the success of this leap-frog technology. To strike an appropriately balance between efforts toward making incremental versus revolutionary changes generally requires a better understanding of the net impact of government-sponsored research.

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