CHAPTER 1

INTRODUCTION

The Office of Energy Efficiency and Renewable Energy (EERE) develops—and encourages consumers and business to adopt—technologies that improve energy efficiency and increase the use of renewable energy. This report describes analysis undertaken by EERE to better understand the extent to which the technologies and market improvements funded by its fiscal year (FY) 2005 Budget Request[1] will make energy more affordable, cleaner, and more reliable.

This benefits analysis helps EERE meet the provisions of the Government Performance and Results Act (GPRA) of 1993 and the President's Management Agenda (PMA). GPRA requires Federal Government agencies to develop and report on output and outcome measures for each program.[2] This EERE benefits analysis supports these GPRA requirements by developing an assessment of the benefits that may accrue to the Nation if the performance goals (outputs) of EERE's programs are realized. The estimates of consumer energy-expenditure savings, energy-system cost savings,[3] carbon emission savings, and reduced reliance on fossil fuels that are reported here result from the increased use of energy-efficient technologies and increased production of renewable energy resources—which are supported by the technology advances and market adoption activities pursued by EERE programs.

Shortly after GPRA was enacted, EERE initiated a corporate approach to benefits analysis that examined the energy, economic, and environmental impacts of program efforts. Through the 1990s, EERE program offices continued to refine their benefits-analysis methodologies and assumptions. An annual external review of the methodologies and assumptions employed was initiated in 1997 and continued through 2001 when EERE was reorganized. Although the benefits analysis has changed since it was initiated 10 years ago, the amount of energy saved or displaced continues to be the key measure of the EERE program impact.

This benefits analysis also supports the President's Management Agenda. The analysis summarized in this report is based on the modeling of program performance goals or outputs. EERE's programs develop these goals based on the following key assumptions:[4]

---

[1] See http://www.eere.energy.gov/office_eere/budget.html.

[2] See the Government Performance Results Act (GPRA) of 1993 at http://www.whitehouse.gov/omb/mgmt-gpra/gplaw2m.html and http://www.whitehouse.gov/omb/circulars/a11/02toc.html

[3] NEMS-GPRA05 estimates consumer expenditure savings, which are the gross savings from avoiding purchased energy. They do not include the incremental investment required to achieve these savings. MARKAL-GPRA05 estimates energy-system costs savings, which includes both the savings from avoiding purchased energy and the incremental investment required for the advanced energy technology.

[4] Achieving program goals is generally not dependent on a single technical pathway, but instead encompasses a number of alternative approaches, of which some may fall short without jeopardizing realization of the final goal. The pursuit of multiple pathways can increase the likelihood of achieving program goals, thereby reducing the risk of the program. Risk is being addressed in a separate EERE effort to develop a standard approach to risk assessment.

- Programs will be funded at the levels requested in DOE's FY 2005 Budget Request;
- Funding levels will remain constant in inflation-adjusted dollars or increase to accommodate key initiatives in particular cases, as indicated;

By basing estimated benefits on budget levels, the analysis addresses the performance-budget integration goal of the PMA. This analysis also provides the benefits sought in the R&D Investment Criteria, developed by the Office of Management and Budget (OMB) for the PMA.

Role of Benefits Analysis in Performance Management

EERE employs a widely used logic model[5] as the foundation for managing its portfolio of efficiency and renewable investments, and for ensuring that these investments provide energy benefits to the Nation. In its simplest form, a logic model identifies budget and other *inputs* to a program, *activities* conducted by the program, and the resulting *outputs* and *outcomes* of those activities. The logic model employed by EERE (**Figure 1.1**) provides an integrated approach that explicitly links requested budget levels to performance goals and estimated benefits—and helps ensure that estimated benefits reflect the funding levels requested. The elements of the logic model, which are specified in GPRA, are included in the annual budget request.

Multiyear Program Plans (MYPPs), developed by each of EERE's 11 programs, address the *inputs* required, the *activities* that will be undertaken with their requested budget, the performance *milestones* they expect to achieve as they pursue these activities, and the resulting products or *outputs* of this effort.[6] Inputs may include cost-shared or leveraged funds, as well as EERE program dollars—and may also include advances by others on which the program builds. Performance milestones capture intermediate points of discernable progress toward outputs and are used by program managers, DOE, OMB, and others to track program progress toward their outputs. Outputs, often referred to as "program goals" or "program performance goals,"[7] are the resulting products or achievements of an overall area of activity. EERE's R&D programs typically specify their outputs in terms of technology advances (*e.g.*, reduced costs, improved efficiency), while deployment programs develop outputs related to their immediate market impacts (*e.g.*, number of homes weatherized). Outputs evolve over time as the program pursues increasing levels of technology performance or market penetration.[8]

This benefits analysis links these program outputs to their market impacts or outcomes. EERE's programs have discernable effects on energy markets, both by reducing the level of energy

---

[5] The logic model is a fundamental program planning and evaluation tool. For more information on logic models, see: Wholey, J. S. (1987). *Evaluability assessment: developing program theory. Using Program Theory in Evaluation*. L. Bickman. San Francisco, Calif., Jossey-Bass. 33. Jordan, G. B. and J. Mortensen (1997). "Measuring the performance of research and technology programs: a balanced scorecard approach." *Journal of Technology Transfer* 22(2). McLaughlin, J. A. and J. B. Jordan (1999). "Logic models: a tool for telling your program's performance story." *Evaluation and Program Planning* 22(1): 65-72.
[6] Appendices B through M provide more information on each program's multiyear program plan and the inputs, activities, milestones, and outputs contained therein.
[7] Some programs derive their outputs through technology-cost simulation models to develop the specific requirements to meet overall program cost and performance goals. Specific details of the representation of the program outputs in NEMS-GPRA05, MARKAL-GPRA-05, and the underlying program analysis and documentation are found in Chapters 4 and 5 of this report and Appendices B through M.
[8] The level of risk for the programs is assessed qualitatively as part of the Office of Management and Budget (OMB) R&D Investment Criteria. EERE is developing a standard approach to assessing technology and program risk.

demand (through efficiency improvements) and by changing the mix of our energy supplies (through increased renewable and distributed energy production). EERE incorporates these two effects in its primary *outcome*—the displacement of conventional energy demand.

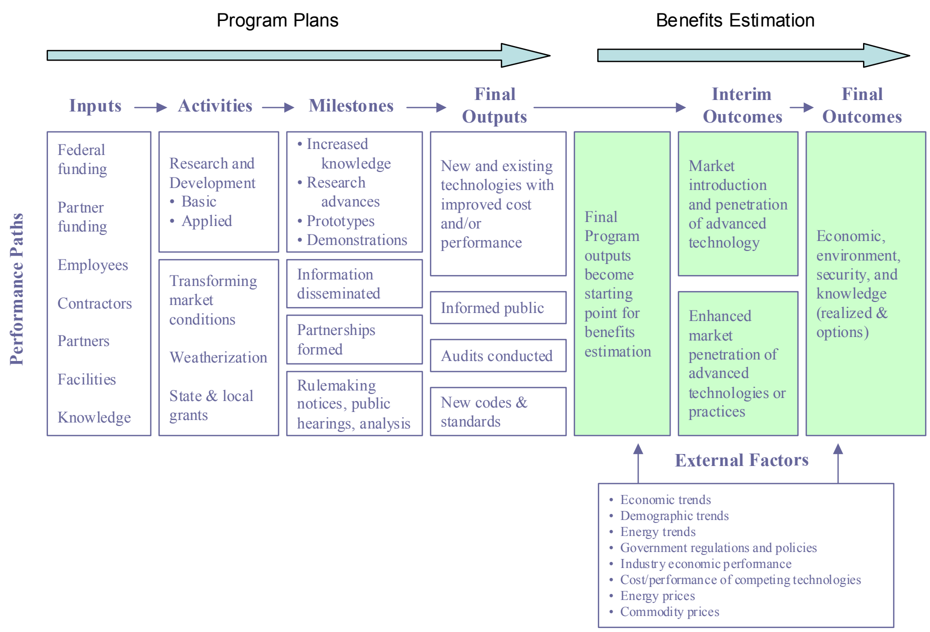

Figure 1.1. Generalized EERE Logic Model

These changes in energy use provide the basis for the economic, environmental, and security benefits estimated here. The extent to which a new technology or a deployment effort changes energy markets will depend on a variety of external factors. The future demand for energy, its price, the development of competing technologies, and other market features (such as consumer preferences) all will contribute to the marketability and total sales of a new technology.

Benefits Framework

The EERE Benefits Framework addresses the last three columns of the logic model: the link between program outputs with resulting outcomes and benefits. The benefits analysis is based on the specific program goals or outputs specified by EERE programs in their program plans and the EERE budget request, as well as estimated future energy market conditions (external factors). EERE estimates its primary outcome—displaced conventional energy consumption—by comparing future energy consumption with and without the contributions of its program outputs. The market impacts of each of the 11 programs are assessed separately and then combined to assess the benefits of EERE's overall portfolio.[9]

[9] EERE's benefits analysis, which measures final outcomes due to EERE programs and a host of other external factors as shown in Figure 1.1., is distinct from impacts analysis, which determines the portion of outcomes having a causal relationship with EERE's actions.

EERE, along with the Office of Fossil Energy (FE), is in the process of adopting a framework initially developed by the National Research Council (NRC) to assess the benefits associated with past EERE research efforts.[10] EERE's annual estimates of prospective benefits have been incorporated into an integrated framework addressing the benefits of both existing and future program activities. The framework is represented in a matrix, in which the rows distinguish among four types of benefits, and the columns represent different elements of time and uncertainty.

This report addresses the three shaded cells of the matrix, reflecting benefits under a business-as-usual energy future (**Figure 1.2**). EERE and FE currently are developing methods for assessing the value to the country of developing technologies that prepare the Nation for unexpected energy needs. These results will be in the "option" column in future reports.[11] Similarly, EERE is in the process of extending the NRC analysis of realized benefits to include its full portfolio.

	Realized Benefits and Costs	Expected Prospective Benefits and Costs	Options Benefits and Costs
Economic Benefits and Costs		✓	
Environmental Benefits and Costs		✓	
Security Benefits and Costs		✓	
Knowledge Benefits and Costs			

Figure 1.2. FY 2005 Benefits Metrics Reported

Completing the cells of this matrix in ways that provide comparable results across programs (and DOE offices) poses a number of analytical challenges, especially in light of the varied portfolio that EERE maintains:

- **Standard baseline(s) and methodological approaches.** EERE uses the Energy Information Administration's (EIA) *Annual Energy Outlook 2003* (*AEO2003*) Reference Case as a consistent starting point for analysis of all of its programs.[12] A standard set of methodological approaches (guidance) is used to assess the incremental improvements to energy efficiency and renewable energy production, resultant from realization of EERE program goals. This guidance is applicable to all of EERE's program activities and markets.

[10] See *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*, National Research Council (2001) for the original framework. DOE's offices of Energy Efficiency and Renewable Energy, Fossil Energy, Nuclear Energy, and Science cosponsored DOE's "Estimating the Benefits of Government-Sponsored Energy R&D" conference in March 2002 to explore ways of extending this framework to include the prospective benefits of program activities. As a result of the conference, the matrix was revised by placing knowledge as a benefit and explicitly showing expected prospective benefits and costs in addition to realized benefits and costs. The conference report is available at www.esd.ornl.gov/benefits_conference.

[11] For its retrospective study, the NRC defined an option as a technology that is fully developed—but for which existing market or policy conditions are not favorable for commercialization. Because current technology choices are known, noncommercial (but developed technologies) are options, by default. A more general definition for prospective analysis—expressed in the Real Options literature—defines a real option as an asset, such as a technological innovation that creates future choices (*i.e.*, options) and establishes an analytic decision-making framework on how to enhance asset value at future points in time. See Dixit, Avinash K., and Robert S. Pindyck, *Investment under Uncertainty*, Princeton University Press, Princeton, New Jersey (1994).

[12] See *The Annual Energy Outlook 2003 with Projections to 2025*, January 2003, DOE/EIA-0383 (2003), available at http://www.eia.doe.gov/oiaf/archive/aeo03/pdf/0383(2003).pdf.

- **Varied markets.** Program activities target all end-use markets (buildings, industry, transportation, and government) and energy-supply markets (use of renewable energy as new sources of liquid and gaseous fuels, and electricity). Because these markets vary enormously in structure, regulation, and consumer preferences, a fairly detailed, market-specific analysis often is needed to gain sufficient understanding of the size and potential receptivity of each market to EERE's activities. EERE strives to incorporate these unique market features that are likely to have a significant impact on the resulting benefits.

- **Varied time frames.** The analytical time frame extends from a few years to the decades that are required for the development of new energy sources, infrastructure, market penetration, and product life cycle. This expansive time frame requires a baseline and analytical tools that can address energy markets in the short, mid-, and long term. This report addresses midterm (5–20 years) and long-term (20–50 years) time frames.

- **Numerous market feedbacks.** EERE technology and deployment efforts can have large enough effects on their respective energy markets that they generate supply or price feedbacks. EERE's products also can interact with each other across their respective energy markets. For example, efficiency improvements in end-use markets can be large enough to forestall the development of new electricity-generating plants, reducing the potential growth of wind and other renewable electricity sources. Past EERE experience indicates that failure to reflect market responses tends to overestimate benefit levels. EERE utilizes integrated energy-economic models to produce final benefit estimates that consider these feedbacks and interactions at the program and portfolio levels.

Benefits Analysis Team

This report summarizes program benefits analysis undertaken by experts in energy technology programs, energy markets, and energy-economic modeling. The primary team members and their areas of responsibility are listed below.

<u>Report Managers</u>

- EERE
    - Integrated: MaryBeth Zimmerman
    - Biomass: Tien Nguyen
    - Buildings: Jerry Dion
    - Distributed Energy Resources (DER): Michael York
    - Federal Energy Management: David Boomsma
    - Geothermal: Cathy Short
    - Hydrogen, Fuel Cells, and Infrastructure Technologies: Jeff Dowd
    - Industry: Peggy Podolak
    - Solar: Tom Kimbis
    - Vehicle Technologies: Phil Patterson
    - Weatherization and Intergovernmental: Michael Gonzalez
    - Wind and Hydropower: Linda Silverman

- Contractors
  - Project Manager: Doug Norland (NREL)
  - Guidance: Patrick Quinlan (NREL), John Mortensen (Independent Consultant)
  - Appendices: Michael Berlinski (NREL)
  - Editorial: Michelle Kubik (NREL)

Analysis Team

- Energy-Economic Integration: Frances Wood, John Holte, Aliza Seelig (OnLocation, Inc.); Chip Friley, John Lee (BNL)
- Biomass: Lynn McLarty (TMS); David Andress, Tracy Carole (Energetics)
- Buildings: Sean McDonald, Dave Anderson, David Belzer, Donna Hostick, (PNNL)
- DER: Chris Marnay (LBNL)
- Federal Energy Management: Daryl Brown, Andrew Nicholls (PNNL)
- Hydrogen and Fuel Cells: Margaret Singh, Matt Kauffman, Phil Patterson (EERE)
- Geothermal: Dan Entingh (PERI)
- Industry: Jim Reed (Independent Consultant)
- Renewables (all): Chris Marnay, Kristina Hamachi LaCommare (LBNL)
- Solar: Robert Margolis (NREL), Jim McVeigh (PERI)
- Vehicle Technologies: Margaret Singh (ANL), Jim Moore (TA Engineering), Elyse Steiner (NREL)
- Weatherization and Intergovernmental Programs (WIP): Sean McDonald, David Anderson, Nancy Moore (PNNL); Elyse Steiner (NREL)
- Wind and Hydropower: Tom Schweizer, Joe Cohen, Jim McVeigh (PERI); Jack Cadogan, James Ahlgrimm (EERE)

In all cases, these lead analysts drew from the studies and expertise of many others. Much of this supporting work can be found in the references provided here and in the appendices.

Report Organization

This report is organized into four additional chapters. **Chapter 2** describes the process and methodology employed by EERE to estimate program and portfolio economic, environmental, and security benefits from its RD&D programs. **Chapter 3** presents the overall results of the savings estimates from the individual programs and from a total EERE portfolio perspective. **Chapter 4** describes, in detail, the estimated midterm benefits of each program area using NEMS-GPRA05. **Chapter 5** describes, in detail, the estimated long-term benefits of each program area using MARKAL-GPRA05.

Thirteen appendices are included. **Appendix A** provides the Baseline and Portfolio Cases. **Appendices B through M** provide program-analysis team inputs for EERE's programs.