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Energy Efficiency and Renewable Energy
U.S. Department of Energy

Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP

April 2003
Prepared for EERE's Office of Planning, Budget Formulation, and Analysis
by Pacific Northwest National Laboratory

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Energy Efficiency and Renewable Energy
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Executive Summary

Pacific Northwest National Laboratory (PNNL) estimated the fiscal year (FY) 2004 energy, environmental, and financial benefits (i.e., metrics) of the technologies and practices in the U.S. Department of Energy's (DOE's) former Office of Building Technology, State and Community Programs (BTS) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE). During the development of the estimates, EERE went through a large-scale reorganization, resulting in the reallocation of the former BTS projects (along with the other former offices) into two new Program Offices: the Office of Building Technologies Program (BT) and the Office of Weatherization and Intergovernmental Program (WIP). The remainder of this document will refer to these projects as BT/WIP for the sake of simplicity.

This effort is referred to as GPRA Metrics because it stems from the requirements of the Government Performance and Results Act (GPRA) of 1993, which mandates the reporting of performance goals and measures. The benefits developed for EERE through the GPRA Metrics effort are submitted to EERE's Office of Planning, Budget Formulation, and Analysis (PBFA) as part of EERE's budget request. The GPRA estimates are also used in the formulation of EERE's performance measures.

This report includes sections that detail the approach and methodology used to estimate future energy, environmental, and financial benefits produced by technologies and practices supported by BT/WIP in the FY 2004. An overview describes the GPRA process and the models used to estimate savings. The body of the document describes the models used and the diffusion curve estimates. Appendixes contain tables of forecasted benefits for all projects through 2030, along with individual project characterizations and overall results of the FY 2004 GPRA effort.

Contents

1.0 Overview of the FY 2004 GPRA Metrics

Pacific Northwest National Laboratory (PNNL) estimated the projected FY 2004 energy, environmental, and financial benefits (i.e., metrics) of the technologies and practices in the U.S. Department of Energy's (DOE's) former Office of Building Technology, State and Community Programs (BTS) within the DOE's Office of Energy Efficiency and Renewable Energy (EERE). During the development of the estimates, EERE went through a large-scale reorganization, resulting in the former BTS projects (along with those of other former offices) being reallocated into two new program offices: the Office of Building Technologies Program (BT) and the Office of Weatherization and Intergovernmental Program (WIP). The remainder of this document will refer to these projects as BT/WIP for simplicity.

EERE initiated the metrics effort in 1994 to develop quantitative measures of project benefits and costs in response to the Government Performance and Results Act (GPRA) of 1993. The supporting analysis and data obtained through the metrics effort are used to estimate and validate progress toward strategic goals and objectives within BT/WIP and DOE, to communicate the benefits of EERE projects to all interested parties, and to defend the budget before Congress.

1.1 Estimating the Energy Savings of BT/WIP Projects

Energy savings for the FY 2004 GPRA metrics were based on the FY 2004 final budget request (dated 02/03/2003). Within each Program (BT and WIP), the budget request is comprised of levels of aggregation. Within this document, these levels are defined as:

- Decision Unit: the highest level of aggregation within the Program; decision units group like-types of projects together (e.g., Residential Buildings Integration projects primarily target residential buildings).
- Project: the budget line-item level. Projects may or may not be comprised of multiple activities for which benefits estimates are developed. In some cases, projects and decision units are equivalent (e.g., Weatherization Assistance).
- Activity: the product, technology, or service for which benefits estimates are developed. In some cases, activities and projects are equivalent (e.g., State Energy Project); in other cases, a project estimate is comprised of multiple activities (e.g., Space Conditioning and Refrigeration R&D includes multiple activities, such as Commercial Refrigeration, HVAC Distribution Systems, Advanced Electric Heat Pump Water Heaters, and Refrigerant Meters).

PNNL estimated the savings at the activity level and then aggregated them to the decision unit level. PNNL estimated WIP benefits for 12 activities, which rolled up into 6 projects and further into 3 WIP decision units. PNNL estimated BT benefits for 25 activities, which rolled up into 13 projects and further into 4 BT decision units. Table 1-1 shows the resulting 7 decision units, 19 BT and WIP projects, and 37 activities.

Table 1-1. Decision Units and Projects Evaluated for FY 2004 GPRA Metrics

Decision Unit	BT/WIP Projects Aggregated for GPRA FY 2004 Metrics	BT/WIP Activities
WIP – Weatherization Assistance	Weatherization Assistance Project	Weatherization Assistance Project
WIP – State Energy Project	State Energy Project	State Energy Project
WIP – Gateway Deployment	Rebuild America	Rebuild America
	Information Outreach	Energy Efficiency Information Outreach
	Training and Assistance for Codes	Building Codes Training & Assistance
	Energy Star	Clothes Washers Refrigerators Electric Water Heaters Gas Water Heaters Room Air Conditioner Compact Fluorescent Lights (CFLs) Dishwashers
BT – Residential Buildings Integration	Residential Technology R&D	Residential Buildings R&D
	Residential Building Codes	Residential Building Codes
	Zero Energy Buildings	Zero Energy Buildings
BT – Commercial Buildings Integration	Commercial Technology R&D	Commercial Buildings R&D
	Commercial Building Codes	Commercial Building Codes
BT – Emerging Technologies	Lighting R&D	Lighting R&D: Controls
	Next Generation Lighting Initiative	Next Generation Lighting Initiative
	Space Conditioning and Refrigeration R&D	Residential HVAC Distribution System Advanced Electric Heat Pump Water Heat Commercial Refrigeration Refrigerant Meter
	Appliances & 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: Window Technologies	Electrochromic Windows Superwindows
	Building Envelope R&D: Thermal Insulation and Building Materials	Quick -Fill Walls R30/30 Year Roofs Moisture/Wet Insulation
	Analysis Tools and Design Strategies	Analysis Tools and Design Strategies
BT – Equipment Standards and Analysis	Equipment Standards and Analysis	Residential Gas Furnaces/Boilers EPAct Standards Distribution Transformers

No single model or approach is capable of capturing or adequately representing the diversity of activities supported by BT/WIP (not to mention the rest of the EERE portfolio). As such, PNNL has adopted a variety of analytical approaches including macro economic models, energy accounting models, and spreadsheets. This section briefly describes the analytical approaches used to estimate energy savings for the FY 2004 budget request for BT and WIP. Each project is characterized in greater detail in the appendixes to this document.

PNNL reports the benefits of BT/WIP projects and technologies at several different levels: they are provided at the Program (BT/WIP) level for use by senior EERE management in considering portfolio options; at the decision unit level for use by Program Managers to assess program direction and future progress toward goals and objectives; and at the project/activity level for use by project managers in planning and execution.

PNNL assessed the benefits for a limited number of defined metrics:

- Energy savings
- Environmental benefits
- Economic/financial metrics
- Employment and income impacts.

The BT/WIP projects produce many other benefits, including reductions in peak energy loads, enhanced security due to reduced oil demand, reduced energy costs for low-income households, and increased comfort and health in buildings; however, these are not currently measured as part of the GPRA process.

The environmental impacts that are estimated as part of the GPRA process are only those that directly related to the burning of fossil fuels; other impacts such as land use and localized water pollution are not measured. Within the economic metrics, the consumer cost savings (or energy cost savings) are simple monetizations of the energy savings and do not include the incremental cost of the new technology or practice; nor are they discounted. For both the environmental impacts and consumer cost savings, calculations are based on the EERE guidance for the GPRA Metrics effort (EERE 2002). Because environmental and economic benefits (energy cost savings) relate directly to projected energy savings, the balance of this overview focuses on just estimates of energy savings.

For most projects, PNNL further 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. The project and decision unit structure used in this document reflect the organizational structure used in the FY 2004 budget request.

The benefits estimates are based on an evaluation of each project to determine the impact of successful project implementation (in other words, each project is assumed to meet its' stated goals). Our analysis considered project goals, technology characteristics (including performance and cost), the targeted market, and project milestones. Not all activities result in readily measurable energy savings as they are intermediate or enabling technologies or practices, or are contributing to the basic understanding (a "knowledge" benefit) of energy use in the building sector. For this GPRA analysis, we selected activities for which it was possible to develop measured energy savings.

The benefits estimates are developed based on a series of assumptions developed project-by-project. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because BT/WIP projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects and that the cost and performance characteristics improve as projects mature or as they near commercialization.

Because the estimates are produced for the budget request, the BT and WIP offices plan for the budget process two years in advance. For FY 2004, we based project characterizations on 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. The project characterizations in Appendixes A and B represent the results of those interviews, reviews, and revisions.

1.2 Modeling Methods Used In Estimating Benefits

PNNL calculated the BT/WIP GPRA estimates of benefits using one of three methods:

- A PNNL adaptation of the National Energy Modeling System (NEMS-PNNL)[a]
- Building Energy Savings Estimation Tool (BESET)
- 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/WIP technologies, such as the whole-building projects (projects that use a systems approach, looking at integration and interaction of building components such as roofs, walls, and equipment and seeking to optimize energy efficiency through consideration of these interactions), because NEMS-PNNL is designed to model specific technologies, not the impacts of groups of interacting technologies.

BESET was built specifically for estimating the benefits of BT/WIP projects and therefore allows various types of projects to be characterized, including whole-building, envelope, and equipment projects. BESET's major disadvantage is that the 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. In addition, BESET cannot model equipment that competes against more than one baseline equipment type.

The disadvantage of BESET's use of endogenous penetration rates is offset, in part, by the incorporation of technology diffusion curves within the analysis. 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. Section 3.0 provides the most complete report of

[a] Any modification or alteration to the official NEMS model must be called out as such; for PNNL's GPRA effort, the modified version used is referred to as NEMS-PNNL.

that study. PNNL estimated diffusion models for each product based on the specification proposed by F.M. Bass (1969). Bass was the first to suggest the "S" curve or logistical functional form for the market diffusion of new products, and his concepts are still widely used in the marketing discipline today. We incorporated the resulting models into the GPRA metrics analysis for many of the projects and technologies not modeled within the NEMS framework. We designed the model development and empirical analysis to generate more credible predictions of the adoption process of important energy-efficiency technologies in the buildings sector. The technologies were placed into four separate categories: lighting, HVAC and refrigeration (HVAC/R), envelope, and other.

PNNL used spreadsheets to model projects not easily modeled in BESET or NEMS-PNNL. For example, because the codes and standards projects previously have developed their own set of spreadsheet tools for estimating impacts, PNNL adapted these tools for the GPRA estimation process. We describe each of the three methods used for deriving energy-saving estimates for the FY 2004 GPRA metrics in more detail in Section 2.0 of this document.

1.3 The National Research Council Methodology

A National Academy of Sciences report (NRC 2001) assessed the outcomes of energy efficiency and fossil energy research from 1978 to 2000. One of the council'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."

The National Research Council committee assumed that the private sector would have developed the technology in the absence of DOE five years after DOE realized the benefits (also known as the "5-year rule"). 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. It should be noted that the NRC studied only R&D programs, so universal adoption of the 5-year rule by all projects, such as rulemaking and information efforts, goes beyond the NRC's intent. As such, this assumption was adopted, in part, as part of the uniform process for assessing prospective (future) benefits of EERE programs.

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/WIP 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 (some projects, such as Weatherization Assistance and Appliance Standards, would most likely not be undertaken by the private sector, and therefore do not have a form of the 5-year rule applied to them). This approach diminishes the BT/WIP project savings in future years, presuming that the private sector is expanding its development and production of these technologies. Figure 1-1 illustrates how applying this acceleration methodology impacts a project's estimates in its most simplified state. Note that the bell-shaped curve in Figure 1-1 depicts the difference (the net benefit from DOE R&D, also shown as the shaded area) between the penetration without DOE R&D and the accelerated penetration with DOE R&D.

Further detail on how the methodology was implemented at the project level is contained in the appendixes' individual project characterizations, where applicable, and is referred to as the National Research Council (NRC) methodology. Because of the arbitrariness of a 5-year rule, PNNL used an "x-year rule," using judgment to assess the length of time the DOE project accelerated full deployment of a product.

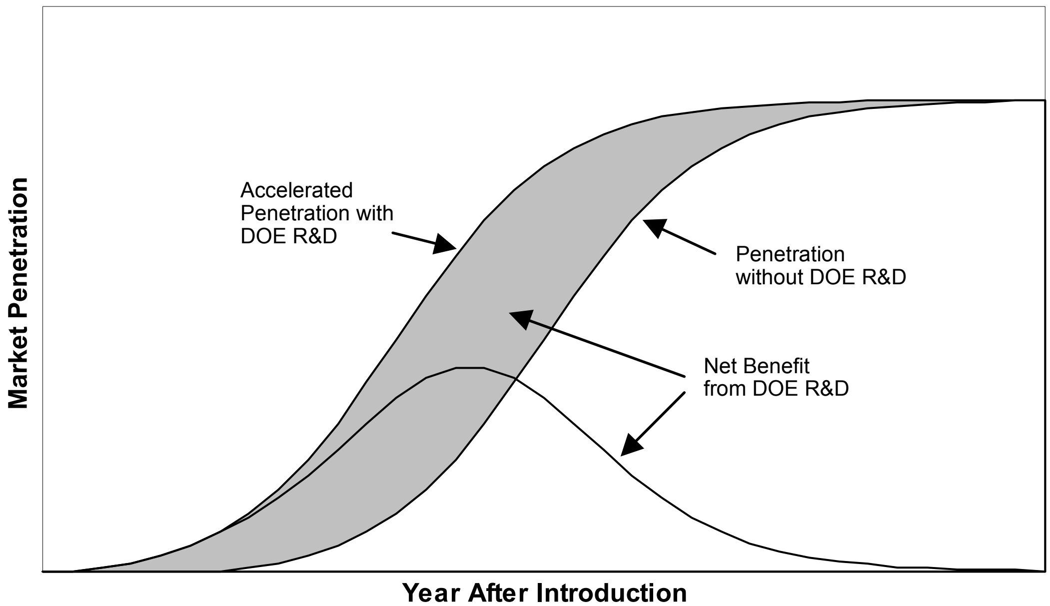

Figure 1-1. Impact of National Research Council Methodology (pure market acceleration case)

1.4 Baseline Inputs

The benefits estimates produced for the GPRA effort represent the estimated future impacts of activity funding. In order to produce the estimated impacts, baseline forecast assumptions must first be established. To the extent possible, the underlying assumptions about building stock forecasts, future equipment efficiencies, future market shares, and future 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 forecasts produced by the Energy Information Administration (EIA), a statistical agency within DOE. For example, the same version of NEMS used in this document was used to produce EIA's *Annual Energy Outlook*.

BESET also has a baseline forecast characterization, which is drawn from NEMS-PNNL, EIA's *Annual Energy Outlook*, the "Residential Energy Consumption Survey," and the "Commercial Buildings Energy Consumption Survey." We verified the consistency of the baseline assumptions of the spreadsheet tools against EIA's data.

1.5 Adjustments to Estimates due to Budget Revisions

The budget formulation process involves much iteration, and the budget requested for various line items may change during that process. First, EERE develops an initial budget; next, an internal Review Budget (IRB) is developed in conjunction with the Chief Financial Officer; eventually, the budget proceeds to the Office of Management and Budget (OMB), and subsequent versions are developed based on an appeal of the OMB pass back. Finally, the budget is formally submitted by the President to Congress (referred to in this document as the final budget request).

The project characterizations driving the benefits estimates are developed through close interaction with the BT/WIP project managers. The characterizations require the project manager to make assumptions based on the requested level of funding, and the characterization then describes what would be accomplished at that level. However, because the budget request amount sometimes changes between the time that the characterization is developed and the time that the budget request is finalized, and also because changes occur between the final budget request (on which the final estimates are based) and the actual allocation, PNNL needs to be able to quickly recalculate the estimated benefits for the various projects.

For small changes in budget levels, PNNL introduces a basic "budget adjustment" to the project estimates. We assume that to get to X savings, a total of Y budget must be spent, where Y is the cumulative budget over the FY 2004-FY 2030 projection period. A change in the annual budget results in a change in the cumulative budget. Revised savings are calculated for each year using the formula: new cumulative budget in year z divided by old cumulative budget in year z. This adjustment mechanism implicitly suggests that either the fraction of expected sales or the performance of the project has changed but does not explicitly tie the change to one factor or the other.

For larger changes, we revisit the project inputs with the BT/WIP project managers to determine the impact of a reduced (or increased) budget. Options for adjusting the models include changing the year of market introduction, changing the impact on sales (market penetration), modifying the performance objective, and adding or removing tasks or technologies within the project (e.g., increased funding in Energy Star may result in developing an Energy Star rating for an additional technology).

The set of energy-savings estimates documented in this report was produced based on the final budget request for FY 2004 (dated 2/3/2003) and projected to FY 2030.

1.6 Calculating Employment and Income Impacts: The ImBuild Model

For DOE, PNNL also assesses the potential economic impacts of its portfolio of projects on national employment and income. PNNL uses a special purpose version of the IMPLAN input-output model called ImBuild II in a companion study covering the same projects analyzed for GPRA (Scott et al. 2003). That study reports energy savings, investments, and impacts on U.S. national employment and earned income by project for selected years to FY 2030. Energy savings and investments from these projects have the potential of creating 297,000 jobs and ~$4.2 billion in earned income (2002 $) by FY 2030. Scott et al. (2003) describes in more detail the employment and earned impacts results and modeling methodology.

The GPRA metrics analysis provides estimates of the energy savings and incremental cost to consumers for all BT and WIP projects, which are the primary inputs used to calculate the employment and income impacts of these programs. When consumer cost information was available, the costs of each BT and WIP project were compared with the next best available technology or design to derive incremental costs for each project. When consumer cost information was not readily available, the incremental cost of the project was derived based on the project's energy cost savings, assuming a payback period on the initial investment. The investment and cost assumptions for each project are included in the appendixes' individual project characterization, where applicable.

1.7 Contents of this Document

The remainder of this document consists of four sections and three appendixes. Section 2.0 provides more detailed information on the methodology behind the development of the GPRA benefits estimates. Section 3.0 provides more detailed information on the technology diffusion curves. Section 4.0 lists the references for the entire document, and Section 5.0 lists the terms used throughout the document.

Three appendixes contain the project-specific information used in estimating benefits. Appendix A summarizes the results and presents the inputs used in developing the BT estimates and presents characterizations of the BT projects. Appendix B summarizes the results and presents the inputs used in developing the WIP estimates and presents characterizations of the WIP projects. Appendix C presents the baseline data used by BESET.

2.0 GPRA Metrics Methodology

This section describes the calculation methodology used within BESET, NEMS-PNNL, and various spreadsheets to estimate the energy savings for BT and selected WIP projects.

2.1 BESET Methodology

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. Finally, BESET produces the input files needed for estimating employment impacts developed in a separate modeling environment (Scott et al. 2003).

BESET can estimate benefits for various projects: whole building, envelope, lighting, HVAC, and water heating. Beginning with the FY 2001 GPRA effort, BESET has been used primarily to model projects that target whole-building energy use. Although BESET can model equipment and envelope projects, those projects are primarily estimated using NEMS-PNNL.

To determine energy savings for specific BT/WIP 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., single family and educational), size (commercial only), income level (residential only), vintage (e.g., new or existing), and climate zone or region. Figure 2-1 illustrates the process used to define the project's targeted market segment within BESET, where certain building types, and building sizes are excluded from the mix (indicated with arrow curving downward), leaving a more specific market to target.

  Once the target market has been identified, PNNL determines penetration into that market using technology diffusion curves (discussed in Section 2.0). Within BESET, market penetration is defined as either the fraction of sales for equipment for new buildings or the fraction of installed base for existing buildings. The penetration model requires only the year of introduction into the market, an estimate of market penetration in 2020 (provided by BT/WIP 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

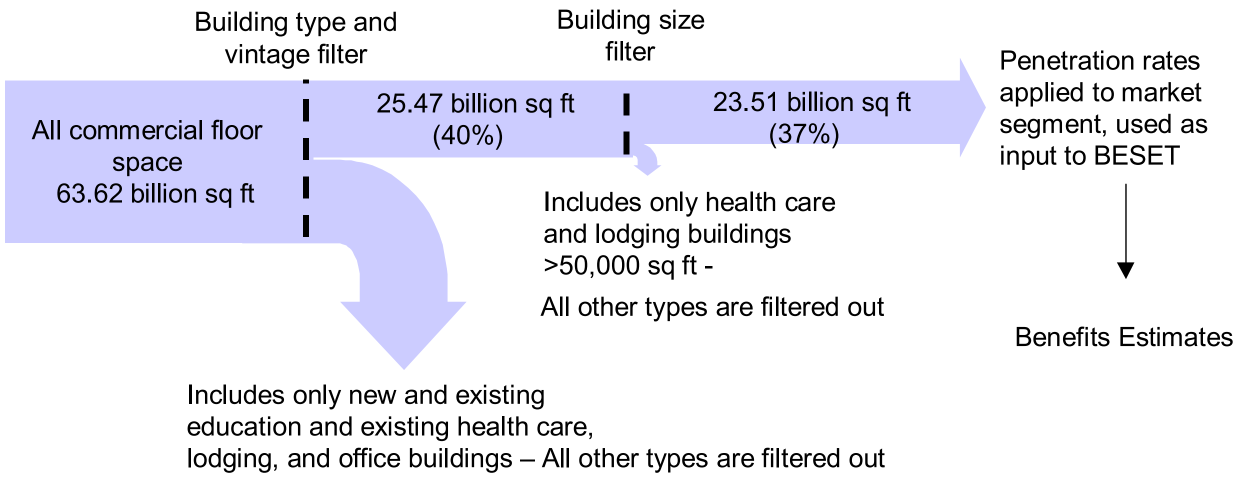

Figure 2-1. Developing the Market Segment (BESET)

would be considered when market penetration is developed; however, the current diffusion model used does not incorporate costs at this time. In addition to private investment, non-energy savings project benefits are also quantified when possible and entered into BESET.

All site-level energy savings and investment estimates are aggregated through a BESET-to-NEMS-PNNL interface. After this aggregation, BESET calculates the primary energy savings, associated emissions reductions, and the dollar value of the energy savings. BESET contains a report generator that aggregates the project- and technology-level benefits into the decision units. The aggregated information is submitted to EERE to be included in the GPRA metrics effort for all EERE sectors. Each of the BESET algorithm approaches is further documented below.

2.1.1 Whole-Building or Envelope Project Approach

This section addresses projects that target the building envelope, a whole-building design approach, or the total building system and that are modeled as improvements to the building envelope. Whole-building projects are characterized by a reduction in space conditioning and/or water heating load resulting from changes in the building system or envelope. The following projects are characterized by the whole-building approach:

- Rebuild America (in WIP – Gateway Deployment decision unit)
- Residential Buildings R&D (in BT – Residential Buildings decision unit)
- Zero Energy Buildings (in BT – Residential Buildings decision unit)
- Commercial Buildings R&D (in BT – Commercial Buildings Integration decision unit)
- Analysis Tools and Design Strategies (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with a whole-building project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market.
- Determine the number of units affected by the BT/WIP project.
- Determine the base space conditioning and water heating end-use loads.

- Determine the space conditioning and water heating end-use loads after project implementation.
- Calculate the energy savings.

Determine Size of the Potential Market

Building stock estimates are used to determine the potential market for each project. Residential and commercial new and existing building stock totals for all years through FY 2020 were provided by EIA's *Annual Energy Outlook 2002*. The years 2021 through 2030 were extrapolated based on the annual growth from 2000 through 2020. The stock estimates have been developed for each market segment (e.g., building type, building vintage, and region) based on several assumptions bulleted below.

The building stock was disaggregated into north and south regions by using the EIA climate zones published in the "Residential Energy Consumption Survey" and the "Commercial Buildings Energy Consumption Survey." Climate zones 1 through 3 (i.e., zones with >4,000 heating-degree days) were designated as the north region, and zones 4 and 5 (i.e., zones with <4,000 heating-degree days) were defined as the south regions. Using this method, approximate percentages of north and south existing units and new construction were estimated:

- Residential single-family and multifamily housing
  - 60% of the existing building stock is in the north.
  - 40% of the existing building stock is in the south.
  - New stock is divided evenly across regions.

- Residential manufactured housing
  - 48% of the existing building stock is in the north.
  - 52% of the existing building stock is in the south.
  - 45% of the new building stock is in the north.
  - 55% of the new building stock is in the south.

- Commercial buildings
  - 59% of the existing building stock is in the north.
  - 41% of the existing building stock is in the south.
  - 55% of the new building stock is in the north.
  - 45% of the new building stock is in the south.

Using the assumptions listed above, we segmented the building stock numbers by building vintage and region. The base year is 2004, and all construction beginning with 2004 is considered new.

Each whole-building project has a specified target market: residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in Appendixes A and B. The potential market for any project is the set of targeted buildings. For example, a project targeting single-family construction includes only the forecasts for new and existing single-family construction in the north and south.

Determine Number of Units Affected by the BT/WIP Project

The number of units affected by the BT or WIP project is calculated using the fraction of sales or fraction of installed base (hereafter referred to as penetration rate) that the project is expected to capture and the building stock. A penetration rate is applied to the appropriate market segment to compute the number of units impacted by the BT/WIP project, as follows:

$$u_{s,b,v,r,t} = P_{s,b,v,r,t} * S_{s,b,v,r,t} \qquad \textit{Equation 2-1}$$

Where u_t = number of units affected in year *t* (billion ft^2 or million households) for building sector *s*, building type *b*, vintage *v*, and region *r*

P_t = penetration rate in year *t* (provided in the project characterizations in Appendixes A and B) for building sector *s*, building type *b*, vintage *v*, and region *r*

S_t = building stock in year *t* (billion ft^2 or million households; see Appendix C, "Baseline Input for BESET") for building sector *s*, building type *b*, vintage *v*, and region *r*.

For new building stock, this product represents the number of impacted units in year *t*. However, for existing buildings, this calculation actually yields a cumulative number, as represented below in Equation 2-2:

$$U_t = \sum_{i=1}^{t} u_i \qquad \textit{Equation 2-2}$$

Where U_t = cumulative total units impacted through year *t*

u_i = number of units impacted in year *i*.

Within BESET, the existing building stock is defined as the total stock at the end of 2003/beginning of 2004, which subsequently gradually declines over time through events such as fires and demolition. The total units affected for existing buildings are, in effect, cumulative to that time period because penetration occurs against that same, entire (although gradually declining) stock each year. As a result, the number of existing-vintage installed units by year must be disaggregated. In other words, only the incremental units affected in a given year should be captured, and this additional step ensures that that occurs. Equation 2-3 explicitly shows this step:

$$u_t = U_t - U_{t-1} = \sum_{i=1}^{t} u_i - \sum_{i=1}^{t-1} u_i, \text{ for } t > 1 \qquad \textit{Equation 2-3}$$

All equations in the BESET methodology section are broken out by building sector, type, vintage, and region. To keep the subsequent equations readable, the subscripts for these categorizations are omitted.

Determine Base Space Conditioning and Water Heating End-Use Loads

End-use loads represent the baseline energy use per square foot (commercial) or per household (residential) for heating, cooling, water heating, and lighting uses. Before the FY 2002 GPRA effort, baseline end-use loads were averaged over all building types and distinguished only by building sector (commercial or residential), building vintage (new or existing), and climate zone (north or south). To more accurately reflect the savings of projects targeting specific buildings, baseline end-use loads are now distinguished by building types (e.g., assembly, education, multifamily, etc.) as well as by vintage and climate zone. End-use loads were updated in June 2000 with energy use information derived from the Facility Energy Decision System (FEDS) (PNNL 2002) to reflect current energy technology and consumption behavior.

The performance improvements for whole-building projects are characterized by reductions in the space conditioning and water heating loads. Therefore, the base energy consumption does not have to be explicitly calculated. Instead, the load reduction is applied to the base load to determine the new load, and the resulting difference in loads is used to calculate energy savings.

Determine Space Conditioning and Water Heating End-Use Loads After Project Implementation

The performance inputs for whole-building projects are defined in terms of percent load reductions. The performance assumptions for each project are described in that project's characterization, included in Appendixes A and B. The load reductions are applied to the corresponding end-use load segment to determine the building-level load reductions by end use, as follows:

$$lr_{e,t} = L_{e,t} * R_{e,t} \qquad \textit{Equation 2-4}$$

Where $lr_{e,t}$ = building-level load reduction (in kBtu/ft^2 or MMBtu/household) for end-use *e*
$L_{e,t}$ = load in year t (kBtu/ft^2 or MMBtu/household) (see Appendix C) for end-use *e*
$R_{e,t}$ = percent load reduction in year *t* (provided in the project characterization) for end-use *e*.

The building-level load reductions are translated into aggregate load reductions by region as follows:

$$LR_{e,t} = lr_{e,t} * u_t \qquad \textit{Equation 2-5}$$

Where $LR_{e,t}$ = regional load reduction in year *t* for end-use *e* (TBtu)
$lr_{e,t}$ = building-level load reduction in year *t* for end-use *e*
u_t = total number of units impacted in year t (calculated in Equation 2-3 [existing] or Equation 2-1 [new]).

At this point, these potential load reductions are cumulated across years of the analysis. Each installation under the project continues to have savings impacts beyond the initial year of installation. The calculations, as shown in the equations below, provide aggregate load reductions in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce savings somewhat over time. For existing buildings:

$$CLR_{e,t} = \sum_{i=1}^{t} LR_{e,i} * \frac{S_t}{S_i}$$ *Equation 2-6*

Where $CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e* (TBtu)
$LR_{e,i}$ = regional load reduction in year *i* for end-use *e*
S_t = building stock in year *t*
S_i = building stock in year *i*.

For new buildings:

$$CLR_{e,t} = \sum_{i=1}^{t} LR_{e,i}$$ *Equation 2-7*

Where $CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e* (TBtu)
$LR_{e,i}$ = regional load reduction in year *i* for end-use *e*.

Calculate Energy Savings

The cumulative regional load reductions must be translated into regional energy savings, requiring baseline assumptions for existing equipment efficiencies and existing equipment market shares. Equipment stock efficiencies were developed from EIA's 1995 *Annual Energy Outlook* and input from project managers. Equipment market shares are broken out by market segment and are estimated based on the 1997 "Residential Energy Consumption Survey," the 1995 "Commercial Buildings Energy Consumption Survey," and original PNNL efforts by Dave Belzer. Because of the lack of a consistent, comprehensive source, the baseline assumptions for equipment efficiencies and equipment shares are not updated annually, but rather on a case-by-case basis as information becomes available. Where applicable, the assumed stock efficiency was increased to meet equipment standards, as these would be the minimum efficiency levels required by law.

First, the cumulative regional load reductions are divided by the baseline existing equipment efficiencies, yielding potential energy savings by equipment type and end use. The potential energy savings assume that each equipment type has 100% of the market, so the actual equipment market shares must then be applied. The market share for each equipment type is multiplied by the potential energy savings to determine the actual energy savings. Equation 2-8 illustrates the energy savings by equipment type and end use calculations:

$$ES_{e,f,q,t} = \frac{CLR_{e,t}}{e_{e,f,q,t}} * M_{e,f,q,t}$$ *Equation 2-8*

Where $ES_{e,f,q,t}$ = energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu/Yr)
$CLR_{e,t}$ = cumulative regional load reduction in year *t* for end-use *e*
$e_{e,f,q,t}$ = equipment efficiency in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$M_{e,f,q,t}$ = market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

The savings calculated are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.2 Equipment Project Approach

This section addresses projects that target equipment, other than lighting. Equipment projects are characterized using new equipment efficiency. The following projects are characterized using the equipment approach:

- Space Conditioning and Refrigeration R&D: Residential HVAC Distribution System (in BT – Emerging Technologies decision unit)
- Space Conditioning and Refrigeration R&D: Advanced Electric Heat Pump Water Heater (in BT – Emerging Technologies decision unit)
- Space Conditioning and Refrigeration R&D: Refrigerant Meter (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with an equipment project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market and the number of units affected by the BT/WIP project.
- Calculate adjustments to the potential market and units affected.
- Determine the base energy consumption of impacted units.
- Determine the energy consumption of impacted units after project implementation.
- Calculate the energy savings.

Determine Size of Potential Market and Number of Units Affected by the BT/WIP Project

Estimates of building stock, base equipment market share and life, project equipment life, and penetration rates all play a role in determining the potential market and the number of units affected by BT/WIP equipment projects. Unlike the relatively straightforward calculations for the whole building projects, equipment calculations are much more complicated. The primary driver behind this is the fact that equipment projects involve devices that fail within a shorter time-frame, relative to the whole building projects, and must be replaced during the analysis period. Despite the additional level of complexity, the initial steps are similar.

Each equipment project has a specified target market – residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in the appendixes to this document.

For the initial calculation, the potential market for any equipment project is, for the targeted building set, the product of the equipment stock and the base equipment replacement factor. The equipment stock is derived through multiplication of the building stock and the equipment market shares. A replacement factor is calculated as the inverse of base equipment life, and indicates the frequency of required replacements. The derivations of equipment stock and the potential market are shown in Equations 2-9 and 2-10, respectively.

$$SE_{e,f,q,t} = S_t * M_{e,f,q,t} \quad \textit{Equation 2-9}$$

Where $SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billions ft² or million households)
S_t = building stock in year *t* (billion ft² or million households)
$M_{e,f,q,t}$ = equipment market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

$$PM_{e,f,q,t} = SE_{e,f,q,t} * \frac{1}{BLife_{e,f,q}} = SE_{e,f,q,t} * BR_{e,f,q} \quad \textit{Equation 2-10}$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households)
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$BR_{e,f,q}$ = base equipment replacement factor for end-use *e*, fuel type *f*, and equipment type *q*.

To initially calculate the number of units affected by the BT/WIP project, the penetration rate is applied to the potential market, as follows:

$$u_{e,f,q,nf,t} = P_{e,f,q,nf,t} * PM_{e,f,q,t} \quad \textit{Equation 2-11}$$

Where $u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf* (billion ft² or million households)
$P_{e,f,q,nf,t}$ = penetration rate in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf* (provided in the project characterization)
$PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households).

In contrast to the case for whole-building projects, the basic units calculation for equipment illustrated here does not require any special handling of existing buildings. With whole-building projects, penetration occurs against the entire building stock. For equipment projects, penetration occurs against only a portion of the building stock because of the use of a replacement factor. As a result, the existing vintage cumulative problem described in the whole-building approach does not exist here.

Calculate Adjustments to Potential Market and Units Affected

While this initial calculation of potential market and impacted units outlined above is fairly simple, the following steps are much more involved. Because base equipment life and project equipment life may differ, a project installation (unit impacted) in year *t* may impact the potential market in future years, which in turn affects project installations in future years. Handling this issue requires an iterative process. The results of the calculations of the previous section serve as inputs to this process.

The issue of differing base and BT/WIP-sponsored equipment lives is not the only complicating factor. The annual (rather than cumulative) nature of new building stock numbers requires unique coding to ensure recompetition of new vintage installations upon failure. This treatment renders new vintage handling consistent with that for existing buildings. Without this added treatment, new vintage installations (whether base equipment or project equipment) would always be replaced with like equipment upon failure, ignoring a valid possibility of additional project penetration.

Beginning with the existing vintage case for the potential market, the calculations of this iterative updating process are outlined below as a series of conditional statements:

$$PM_{e,f,q,t} = \left(If\,(t\text{-}1) \geq BLife_{e,f,q} \; then \; \frac{PM_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t-BLife_{e,f,q})}} * SE_{e,f,q,t}, \; else \; PM_{e,f,q,t} \right) - \left(If\,(t\text{-}1) \geq BLife_{e,f,q} \; then \; \frac{u_{e,f,q,nf,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}BLife_{e,f,q})}} * SE_{e,f,q,t}, \; else \; 0 \right) + \left(If\,(t\text{-}1) \geq PLife_{e,f,q} \; then \; \frac{u_{e,f,q,nf,(t\text{-}PLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}PLife_{e,f,q})}} * SE_{e,f,q,t}, \; else \; 0 \right)$$

Equation 2-12

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*.

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For new buildings: *Equation 2-13*

$$PM_{e,f,q,t} = \left(SE_{e,f,q,t}\right) + \left(If\,(t\text{-}1) \geq BLife_{e,f,q} \; then \; PM_{e,f,q,(t-BLife_{e,f,q})} * \left(1\text{-}P_{e,f,q,nf,(t\text{-}BLife_{e,f,q})}\right), \; else \; 0 \right) + \left(If\,(t\text{-}1) \geq PLife_{e,f,q} \; then \; u_{e,f,q,nf,(t-PLife_{e,f,q})}, \; else \; 0 \right)$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$P_{e,f,q,nf,t}$ = penetration rate in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*
$u_{e,f,q,nf,t}$ = number of units affected in year *t* for end-use *e*, existing fuel type *f*, equipment type *q*, and new fuel *nf*.

These calculations are carried out for all years sequentially for each market segment, beginning with the first year. After the potential market is recalculated for a given year, the impacted units for that year must be recalculated, using Equation 2-11.

Determine Base Energy Consumption of Impacted Units

Building-level base energy consumption is calculated by dividing end-use loads by base equipment efficiencies. End-use loads represent the baseline service requirements per square foot (commercial) or per household (residential) for heating, cooling, and water heating. As such, they must be divided by an efficiency to determine energy consumption:

$$bc_{e,f,q,t} = \frac{L_{e,t}}{e_{e,f,q,t}}$$ *Equation 2-14*

Where $bc_{e,f,q,t}$ = building-level base consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (kBtu/ft² or MMBtu/household)

$L_{e,t}$ = end-use load in year *t* for end-use *e* (kBtu/ft² or MMBtu/household) (see Appendix C)

$e_{e,f,q,t}$ = base equipment efficiency in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

Multiplying this result by the number of impacted units yields regional base consumption yields the following:

$$BC_{e,f,q,t} = bc_{e,f,q,t} * u_{e,f,q,t}$$ *Equation 2-15*

Where $BC_{e,f,q,t}$ = regional base consumption of impacted units in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$bc_{e,f,q,t}$ = building-level base consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (kBtu/ft² or MMBtu/household)

$u_{e,f,q,t}$ = total number of units impacted in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft² or million households).

Because the final goal is calculating energy savings associated with impacted units, deriving total base consumption is not necessary; rather base consumption associated with impacted units only suffices.

At this point, the consumption figures are cumulated across years of the analysis. Each piece of equipment continues to consume energy throughout its lifetime. Therefore, in a given year, consumption may result from equipment installed in several previous years as well. The calculations, as shown in the equations below, provide aggregate energy consumption in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce consumption somewhat over time. To compare the base and project equipment's energy usage appropriately, the base consumption is cumulated over the lifetime of the project equipment. For existing buildings:

$$CBC_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} BC_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for } t > PLife$$ *Equation 2-16*

$$CBC_{e,f,q,t} = \sum_{i=1}^{t} BC_{e,f,q,i} * \frac{S_t}{S_i}, \text{for t} \leq \text{PLife}$$ *Equation 2-17*

Where $CBC_{e,f,q,t}$ = cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)

$BC_{e,f,q,i}$ = regional base energy consumption in year *i* for end-use *e*, fuel type *f*, and equipment type *q*

S_t = building stock in year *t*

S_i = building stock in year *i*

$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings:

$$CBC_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} BC_{e,f,q,i}, \text{for t} > \text{PLife}$$ *Equation 2-18*

$$CBC_{e,f,q,t} = \sum_{i=1}^{t} BC_{e,f,q,i}, \text{for t} \leq \text{PLife}$$ *Equation 2-19*

Where $CBC_{e,f,q,t}$ = cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)

$BC_{e,f,q,i}$ = regional base energy consumption in year *i* for end-use *e*, fuel type *f*, and equipment type *q*

$Plife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

Determine Energy Consumption of Impacted Units After Project Implementation

The performance inputs for equipment projects are defined in terms of new equipment efficiencies. The performance assumptions for each project are described in that project's characterization, included in Appendix A (BT projects) and Appendix B (WIP projects) of this document. A directly parallel process to that described in the previous section is used to calculate consumption associated with the project equipment. In this case, the initial step uses the performance inputs for the project equipment, rather than the base equipment efficiency:

$$pc_{e,nf,q,t} = \frac{L_{e,t}}{p_{e,nf,q,t}}$$ *Equation 2-20*

Where $pc_{e,nf,q,t}$ = building-level program consumption in year *t* for end-use *e*, new fuel *nf*, and equipment type *q* (kBtu/ft^2 or MMBtu/household)

$L_{e,t}$ = load in year *t* for end-use *e* (kBtu/ft^2 or MMBtu/household) (see Appendix C)

$p_{e,nf,q,t}$ = project equipment efficiency in year *t* for end-use *e*, new fuel *nf*, and equipment type *q*.

All other steps toward deriving cumulative regional project energy consumption, CPC_t, are identical to those described in the previous section.

Calculate Energy Savings

With equipment projects, a significant probability of fuel switching exists. To calculate energy savings where the base fuel type is the same as the BT/WIP project fuel type, project consumption is subtracted from base consumption:

$$ES_{e,f,q,t} = CBC_{e,f,q,t} - CPC_{e,nf,q,t} \qquad \textit{Equation 2-21}$$

Base fuel savings where the base fuel type is different from the project fuel type are simply the entire base fuel use:

$$ES_{e,f,q,t} = CBC_{e,f,q,t} \qquad \textit{Equation 2-22}$$

Project fuel savings where the base fuel type is different from the project fuel type are recorded as the negative of project consumption:

$$ES_{e,nf,q,t} = -CPC_{e,nf,q,t} \qquad \textit{Equation 2-23}$$

Where $ES_{e,f,q,t}$ = energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$CBC_{e,f,q,t}$ = cumulative regional base energy consumption in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$CPC_{e,nf,q,t}$ = cumulative regional program energy consumption in year *t* for end-use *e*, new fuel *nf*, and equipment type *q* (TBtu).

These savings (with some being negative) are combined and summed over end uses and equipment to provide the final net energy savings. The final net energy savings are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.3 Lighting Project Approach

This section addresses projects targeting lighting that are modeled using BESET. Lighting projects are characterized by a change in the measure of light output per unit of power, or lumens per watt. The following projects are characterized by the lighting approach:

- Energy Star: CFLs (in WIP – Gateway Deployment decision unit)
- Appliances & Emerging Technologies R&D: Recessed can lights (in BT – Emerging Technologies decision unit)
- Appliances & Emerging Technologies R&D: R-Lamps (in BT – Emerging Technologies decision unit).

Calculating the energy savings associated with a lighting project involves the following steps, which are discussed in the next subsections:

- Determine the size of the potential market and the number of units affected by the BT/WIP project.
- Calculate adjustments to the potential market and units affected.
- Calculate the lighting energy savings.

- Calculate the heating and cooling interactive effects factors.
- Calculate the change in space conditioning energy use due to interactive effects.
- Derive the final energy savings.

Determine Size of Potential Market and Number of Units Affected by the BT/WIP Project

Unlike whole-building projects, lighting projects involve equipment that fails and must be replaced during the analysis period. Despite this additional level of complexity, the initial steps are similar.

Each lighting project has a specified target market: residential and/or commercial (and their subsets), new and/or existing vintages, and north and/or south regions. The target market for each project is described in that project's characterization, included in Appendixes A and B.

For the initial calculation, the potential market for any lighting project is, for the targeted building set, the product of the equipment stock and the base equipment replacement factor. The equipment stock is derived by multiplying the building stock and the equipment market shares. A replacement factor is calculated as the inverse of base equipment life and indicates the frequency of required replacements. The derivations of equipment stock and the potential market are shown in Equations 2-24 and 2-25, respectively.

$$SE_{e,f,q,t} = S_t * M_{e,f,q,t}$$ *Equation 2-24*

Where $SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft^2 or million households)
S_t = building stock in year *t* (billion ft^2 or million households)
$M_{e,f,q,t}$ = equipment market share in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

$$PM_{e,f,q,t} = SE_{e,f,q,t} * \frac{1}{BLife_{e,f,q}} = SE_{e,f,q,t} * BR_{e,f,q}$$ *Equation 2-25*

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft^2 or million households)
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft^2 or million households)
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$BR_{e,f,q}$ = base equipment replacement factor for end-use *e*, fuel type *f*, and equipment type *q*.

To initially calculate the number of units affected by the BT/WIP project, the penetration rate is applied to the potential market, as follows:

$$u_{e,f,q,t} = P_{e,f,q,t} * PM_{e,f,q,t}$$ *Equation 2-26*

Where $u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft2 or million households)

$P_{e,f,q,t}$ = penetration rate in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (provided in the project characterization)

$PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (billion ft2 or million households).

In contrast to whole-building projects, the basic units calculation for lighting illustrated here does not require any special handling of existing buildings. With whole-building projects, penetration occurs against the entire building stock. For lighting, penetration occurs against only a portion of the building stock because a replacement factor is used. As a result, the existing vintage cumulative problem described in the whole-building approach does not exist here.

Calculate Adjustments to the Potential Market and Units Affected

While this initial calculation of potential market and impacted units outlined above is fairly simple, the following steps are much more involved. Because base equipment life and project equipment life may differ (e.g., lives of CFLs and incandescents), a project installation (unit impacted) in year *t* may impact the potential market in future years, which in turn affects project installations in future years. Handling this issue requires an iterative process. The results of the calculations of the previous section serve as inputs to this process.

The issue of differing base and BT/WIP project lives is not the only complicating factor. The annual (rather than cumulative) nature of new building stock numbers requires unique coding to ensure recompetition of new vintage installations upon failure. This treatment renders new vintage handling consistent with that for existing buildings. Without this added treatment, new vintage installations (whether base equipment or project equipment) would always be replaced with like equipment upon failure, ignoring a valid possibility of additional project penetration.

Beginning with the existing vintage case for the potential market, the calculations of this iterative updating process are outlined below as a series of conditional statements:

$$\begin{aligned} PM_{e,f,q,t} = &\left(If\,(t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{PM_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t-BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ PM_{e,f,q,t} \right) \\ &- \left(If\,(t\text{-}1) \geq BLife_{e,f,q}\ then\ \frac{u_{e,f,q,(t\text{-}BLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}BLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right) \\ &+ \left(If\,(t\text{-}1) \geq PLife_{e,f,q}\ then\ \frac{u_{e,f,q,(t\text{-}PLife_{e,f,q})}}{SE_{e,f,q,(t\text{-}PLife_{e,f,q})}} * SE_{e,f,q,t},\ else\ 0 \right) \end{aligned} \qquad \text{Equation 2-27}$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*

$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*

$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings: *Equation 2-28*

$$PM_{e,f,q,t} = \left(SE_{e,f,q,t}\right) + \left(If\ (t\text{-}1) \geq BLife_{e,f,q}\ then\ PM_{e,f,q,(t-BLife_{e,f,q})} * \left(1\text{-}P_{e,f,q,(t\text{-}BLife_{e,f,q})}\right),\ else\ 0\right) + \left(If\ (t\text{-}1) \geq PLife_{e,f,q}\ then\ u_{e,f,q,(t-PLife_{e,f,q})},\ else\ 0\right)$$

Where $PM_{e,f,q,t}$ = potential market in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$BLife_{e,f,q}$ = base equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$ = project equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*
$SE_{e,f,q,t}$ = equipment stock in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$P_{e,f,q,t}$ = penetration rate in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = number of units affected in year *t* for end-use *e*, fuel type *f*, and equipment type *q*.

These calculations are carried out for all years sequentially for each market segment, beginning with the first year. After the potential market is recalculated for a given year, the impacted units for that year must be recalculated, using Equation 2-26 above.

Calculate Lighting Energy Savings

The performance inputs for lighting projects are defined in terms of light output per unit of power, or lumens per watt. The performance assumptions for each project are described in that project's characterization, included in Appendixes A and B. Ratios of the base and project efficacies are applied to the corresponding end-use load segment to determine the building-level energy savings by end use, as follows:

$$es_{e,f,q,t} = \left(1 - \frac{e_{base,e,f,q,t}}{e_{project,e,f,q,t}}\right) * L_{e,t}$$ *Equation 2-29*

Where $es_{e,f,q,t}$ = building-level energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (in kWh/ft^2 or kWh/household)
$L_{e,t}$ = load in year *t* for end-use *e* (kWh/ft^2 or kWh/household) (see Appendix C)
$e_{project,e,f,q,t}$ = efficacy of program equipment in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (lumens/watt) (provided in the project characterization)
$e_{base,e,f,q,t}$ = efficacy of base case equipment in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (lumens/watt).

Unlike the calculations for whole-building projects, market shares do not have to be incorporated or efficiencies do not have to be divided to derive lighting energy savings from end-use load data. The reason is that the load data for the lighting end-use are actually consumption figures, whereas load data for other end uses represent service requirements.

If the lighting load were to be input into BESET in a similar fashion as the other end uses, the data would be entered in lumens/ft^2 rather than the current kWh/ft^2.

After the building-level lighting energy savings are converted to kBtu/ft^2 and MMBtu/household, they are then translated into aggregate lighting energy savings by region as follows:

$$ES_{e,f,q,t} = es_{e,f,q,t} * u_{e,f,q,t} \qquad \textit{Equation 2-30}$$

Where $ES_{e,f,q,t}$ = regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$es_{e,f,q,t}$ = building-level energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q*
$u_{e,f,q,t}$ = total number of units impacted in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (calculated in Equation 2-26).

At this point, these energy savings are cumulated across years of the analysis. Each installation under the project continues to have savings impacts beyond the initial year of installation. Installed lighting continues to generate savings until the end of its life. Therefore, in a given year, savings may be realized from project equipment installed in several previous years as well. The calculations, as shown in the equations below, provide aggregate energy savings in each year, while taking into account the effect of declining building stock for existing buildings. This declining building stock acts to reduce savings somewhat over time. For existing buildings, the calculations are as follows:

$$CES_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} ES_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t > PLife} \qquad \textit{Equation 2-31}$$

$$CES_{e,f,q,t} = \sum_{i=1}^{t} ES_{e,f,q,i} * \frac{S_t}{S_i}, \text{ for t} \leq \text{PLife} \qquad \textit{Equation 2-32}$$

Where $CES_{e,f,q,t}$ = cumulative regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (Tbtu)
$ES_{e,f,q,i}$ = regional energy savings in year *i* for end-use *e*, fuel type *f*, and equipment type *q*
S_t = building stock in year *t*
S_i = building stock in year *i*
$PLife_{e,f,q}$ = program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

For new buildings:

$$CES_{e,f,q,t} = \sum_{i=(t-PLife_{e,f,q})}^{t} ES_{e,f,q,i}, \text{ for t > PLife} \qquad \textit{Equation 2-33}$$

$$CES_{e,f,q,t} = \sum_{i=1}^{t} ES_{e,f,q,i}, \text{ for t} \leq \text{PLife} \qquad \textit{Equation 2-34}$$

Where $CES_{e,f,q,t}$ = cumulative regional energy savings in year *t* for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$ES_{e,f,q,i}$	=	regional energy savings in year *i* for end-use *e*, fuel type *f*, and equipment type *q*
$PLife_{e,f,q}$	=	program equipment life expectancy for end-use *e*, fuel type *f*, and equipment type *q*.

Calculate Heating and Cooling Interactive Effects Factors

A change in lighting consumption significantly impacts other end uses as well. As more efficient lighting is incorporated in buildings, heating loads can be expected to increase, while cooling loads should be reduced. BESET incorporates interactive effects coefficients as inputs, which are used to derive heating and cooling load change factors. For more information on the derivation of the coefficients, see Appendix C. As Appendix C describes, the interactive factors are calculated using the following equations:

$$\Delta heat = a * \Delta L^{b}$$ *Equation 2-35*

$$\Delta cool = c * \Delta L^{2} + d * \Delta L$$ *Equation 2-36*

Where a, b, c, and d are the interactive effects coefficients

Δheat	=	the fractional change in heating load
Δcool	=	the fractional change in cooling load
ΔL	=	the percentage reduction in lighting load.

To calculate the necessary input, ΔL, the baseline lighting consumption first must be determined. For existing buildings:

$$BC_{t} = L_{t} * S_{t}$$ *Equation 2-37*

Where

BC_t	=	base lighting consumption in year *t* (billion kWh for commercial and industrial, million kWh for households)
L_t	=	lighting end-use load in year *t* (kWh/ft^2 or kWh/household)
S_t	=	building stock in year *t* (billion ft2 or million households).

Because new building stock is annual, rather than cumulative, the calculation requires summation of the energy usage, which yields consumption of all new buildings in year *t*. For new buildings:

$$BC_{t} = \sum_{i=1}^{t} L_{i} * S_{i}$$ *Equation 2-38*

Where

BC_t	=	base lighting consumption in year *t* (billion kWh for commercial and industrial, million kWh for households)
L_i	=	lighting end-use load in year *i* (kWh/ft^2 or kWh/household)
S_i	=	building stock in year *i* (billion ft^2 or million households).

After the base consumption results are converted to TBtu, the percentage reduction in lighting load can be calculated. The previously calculated cumulative regional lighting energy savings serves as the numerator:

$$\Delta L = \left(\frac{CES_t}{BC_t} \right) * 100$$ *Equation 2-39*

Where ΔL = the percentage reduction in lighting load
CES_t = cumulative regional lighting energy savings in year *t* (TBtu)
BC_t = base lighting consumption in year *t* (TBtu).

At this point, the required components for calculating the interactive effects factors are available. Using Equations 2-35 and 2-36, Δheat and Δcool are computed.

Calculate Change in Space Conditioning Energy Use Due to Interactive Effects

The load changes from interactive effects are calculated by applying the interactive effects factors to the cumulative regional lighting energy savings (calculated previously in Equations 2-31 through 2-34). As noted earlier, as lighting efficiency increases, cooling loads decrease and heating loads increase. As a result, the calculated values for Δheat are positive, and those for Δcool are negative. Because the load reduction, rather than the change in load, is the desired output, a sign change is applied in the following calculation:

For heating:

$$ILR_{e,f,q,t} = CES_{e,f,q,t} * (-\Delta heat)$$ *Equation 2-40*

For cooling:

$$ILR_{e,f,q,t} = CES_{e,f,q,t} * (-\Delta cool)$$ *Equation 2-41*

Where $ILR_{e,f,q,t}$ = load reductions in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
$CES_{e,f,q,t}$ = cumulative regional energy savings for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)
Δheat = the fractional change in heating load
Δcool = the fractional change in cooling load.

These load reductions must be translated into energy savings. To do this, baseline assumptions regarding existing equipment efficiencies and existing equipment market shares are used. First, the load reductions resulting from interactive effects are divided by the baseline existing equipment efficiencies, which yields potential energy savings by equipment type and end use. The potential energy savings assume that each equipment type has 100% of the market, so the actual equipment market shares must then be applied. The market share for each equipment type is multiplied by the potential energy savings to determine the actual energy savings. Equation 2-42 illustrates the energy savings by equipment type and end use calculations:

$$IES_{e,f,q,t} = \frac{ILR_{e,f,q,t}}{e_{e,f,q,t}} * M_{e,f,q,t}$$ *Equation 2-42*

Where $IES_{e,f,q,t}$ = energy savings in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$ILR_{e,f,q,t}$ = load reductions in year t due to interactive effects for end-use *e*, fuel type *f*, and equipment type *q* (TBtu)

$e_{e,f,q,t}$ = equipment efficiency in year t for end-use *e*, fuel type *f*, and equipment type *q*

$M_{e,f,q,t}$ = equipment market share in year t for end-use *e*, fuel type *f*, and equipment type *q*.

Derive Final Energy Savings

The lighting energy savings and the space-conditioning energy savings are combined and summed over end uses and equipment to provide the final net energy savings. The final net energy savings are aggregated by building sector, type, vintage, region, and fuel type to determine the total site electric savings, total natural gas savings, and total oil savings.

2.1.4 Other Components

This section addresses calculations made within BESET that occur after the individual energy algorithms described above. Each of the following computations applies not only to BESET-estimated projects but also to projects with savings estimated by NEMS-PNNL or spreadsheets models. For projects estimated by methods other than BESET, site energy savings (electric, gas, and oil), investment, and any non-energy costs are first imported into BESET. These inputs are broken out by building sector, type, vintage, region, and year, as are all final outputs of the calculations described below.

Calculate Primary Energy Savings

For BESET-estimated projects, site energy savings are calculated within the algorithms already discussed above. For other projects, site energy savings are provided to BESET as an input. Total site energy consists of site electric, natural gas, and fuel oil savings. To derive primary electric savings, the exogenous site electricity savings are multiplied by a year-specific electricity conversion factor within BESET (see Appendix C). Primary non-electric savings consists of the sum of natural gas and oil savings. Summation of primary electricity and primary non-electric savings yields the total net primary energy savings. The units for all of these data are TBtu.

Calculate Emissions Reductions and Energy Cost Savings

BESET input data include energy prices and site-energy emission factors, both of which are building sector-, fuel- (electric, gas, and oil), and year-specific (see Appendix C). Emission factors are included for carbon equivalent emissions, sulfur dioxide (SO_2), nitrous oxides (NO_x), volatile organic compounds (VOCs), particulate matter (PM), and carbon monoxide (CO). EERE's official GPRA guidance provides the various factors used (EERE 2002, Appendix B). Factors are multiplied by site energy savings, and prices are multiplied by the respective fuel savings. The resulting energy cost savings are reported in millions of dollars, and the emissions reductions are represented as millions of metric tons (MMton) avoided.

Determine Required Investment and Non-energy Costs

For projects estimated outside of BESET, investment and non-energy costs are provided as an input to BESET. For BESET-estimated projects, investment and non-energy costs are output as part of the process, and their estimation relies on the installed units calculated in the above algorithms. These units are in terms of either million households (residential), or billion square feet (commercial) building sectors. Per-unit equipment costs (dollars per square foot or dollars per household) are multiplied by installed units, as Equation 2-43 shows:

$$I_t = c_t * u_t \qquad \text{Equation 2-43}$$

where I_t = investment in year *t*
c_t = per-unit installed cost in year *t*
u_t = number of units impacted in year *t*.

Similarly, non-energy costs are calculated as follows:

$$NE_t = ne_t * u_t \qquad \text{Equation 2-44}$$

where NE_t = non-energy cost in year *t*
ne_t = per-unit non-energy cost in year *t*
u_t = number of units impacted in year *t*.

Each of these calculations is performed for base costs, BT/WIP project costs, and the incremental costs. After necessary conversions, the resulting investment and non-energy costs are reported in millions of dollars.

2.2 General Methodology Using NEMS-PNNL

Many of the projects in BT's Emerging Technologies and Equipment Standards decision units and WIP's Gateway Deployment decision unit 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/WIP-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. NEMS-PNNL is coded to allow several possible assumptions to be used about consumer behavior to model this selection process. For the GPRA effort, the menu of equipment was changed to include relevant BT/WIP-sponsored project equipment, technological innovations, and standards.

The NEMS-PNNL design can accommodate various technology choices. For the GPRA FY 2004 metrics, the NEMS-PNNL data input was adjusted to reflect BT/WIP technology choices. For BT/WIP projects that target efficiency of the building envelope (or shell), specific shell-efficiency indices were read into the model.

The NEMS-PNNL commercial and residential demand modules generate forecasts of energy demand (energy consumption) for the commercial and residential sectors. The commercial demand module generates fuel consumption forecasts for electricity, natural gas, and distillate fuel oil. These forecasts are based on energy prices and macroeconomic variables from the NEMS system, combined with external data sources. The residential model uses energy prices and macroeconomic indicators to generate energy consumption by fuel type and census division in the residential sector. The commercial and residential demand modules are described in the following subsections.

2.2.1 Commercial Demand

This module develops projects of energy consumption by major types of commercial buildings, including assembly, education, food service, food sales, health care, lodging, mercantile and service, office buildings, and warehouses. Commercial energy demand within NEMS-PNNL is calculated in four basic steps:

1. Forecast commercial sector floorspace.
2. Forecast energy services such as space conditioning equipment, lighting, water heating, and refrigeration.
3. Select specific technologies to meet the demand of energy services, which involves modeling consumer behavior and capturing the decision between such equipment as incandescent lights and fluorescent lights.
4. Determine how much energy will be consumed by the equipment chosen to meet the demand for energy services.

The third step is a key element in calculating the estimated energy savings of a given technology promoted by a particular BT/WIP project. Within this step, consumers are assumed to purchase energy-using equipment to meet three types of service demands: services for new buildings, replacement of old equipment that is at the end of its technical life, and replacement of old equipment that is at the end of its economic life (although it still may be technically viable). The NEMS-PNNL commercial model is structured to allow the use of several possible assumptions about consumer behavior to model this decision process. The assumptions are designed to represent empirically the range of economic factors that most influence the consumer’s decision and include the following:

- Consumer buys the equipment with the minimum life-cycle cost.
- Consumer buys equipment that uses the same fuel as existing and retiring equipment but minimizes costs across technologies using that fuel.
- Consumer buys (or keeps) the same technology as the existing and retiring equipment but chooses among different efficiency levels based on minimum life-cycle cost.

The model is designed to choose among a discrete set of technologies that are exogenously characterized by commercial availability, capital costs, operating and maintenance costs, efficiencies, and lifetime. For GPRA metrics, the menu of equipment may be altered to include relevant BT/WIP project equipment, technological innovations, and standards. The NEMS-PNNL design can accommodate a changing menu of technology choices, recognizing that changes in energy prices and consumer demand may significantly change the set of relevant technologies that the model user wishes to consider.

2.2.2 Residential Demand

The residential sector demand module includes single-family, multifamily, and mobile home dwellings. Residential energy demand is modeled using a sequence of five steps:

1. Forecast housing stock.
2. Select the specific technologies to meet the demand for each energy service (e.g. furnaces and heat pumps).
3. Forecast appliance stocks that are required by each end-use service.
4. Forecast changes in building-shell integrity; building-shell efficiency in new construction is assumed to improve over the forecast period because of stricter building codes and other efficiency projects and may fluctuate in response to fuel price changes from the base year.
5. Calculate the energy consumed by the equipment chosen to meet the demand for energy services.

As with the commercial model, the GPRA metrics methodology involves modifying the technology performance and cost inputs to reflect the BT/WIP-developed equipment. The technology and equipment selection simulates the behavior of residential consumers based on the relative importance of life-cycle costs, capital costs, and operating costs of competing technologies within a service. Decisions on new and replacement equipment reflect additional factors beyond the traditional life-cycle cost methodology, including space heating fuel choice and previous equipment choices. The technology and equipment selection allocates end-use services based on a defined equipment menu of the various technologies and fuels that compete in the market.

2.2.3 Methodology for Market Transformation-Type Projects

This section discusses the methodological approach to calculating energy savings for projects that attempt to increase sales by modifying consumer behavior. The following projects are characterized in NEMS-PNNL by changes to consumer behavior assumptions:

- Energy Star gas and electric water heaters (in WIP – Gateway Deployment decision unit)
- Energy Star refrigerators (in WIP – Gateway Deployment decision unit)
- Energy Star clothes washers (in WIP – Gateway Deployment decision unit)
- Energy Star room air conditioners (in WIP – Gateway Deployment decision unit)
- Energy Star dishwashers (in WIP – Gateway Deployment decision unit).

The modifications to the NEMS-PNNL input file (RTEKTY) for each appliance with an Energy Star project are described more fully in the project characterizations for Energy Star in Appendix B. That appendix documents the baseline assumptions made by EIA, the changes in the Beta1 coefficients, and the resulting changes in the market shares for the most energy-efficient products. For a few appliances, some changes were made in the baseline assumptions made by EIA. The reasons for these changes are briefly discussed.

The two modeling parameters are labeled by EIA as Beta1 and Beta2. Beta1 is used as multiplicative factor with the initial cost of the appliance, and Beta2 is used to multiply the annual energy cost. The sum of the two products (i.e., Beta1 * initial cost + Beta2 * operating cost) is used in the logit specification to yield market shares for each technology. These coefficients are specific to each equipment type and fuel type. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for the specific appliance. The Beta1 and Beta2 coefficients are contained with the cost and efficiency data inputs in the file RTEKTY. In the residential NEMS module, the Beta1 and Beta2 coefficients vary among appliances, as do the resulting discount rates. For example, the implied discount rate for refrigerators is 16%. On the other hand, the discount rate is estimated to be over 80% for electric water heaters.

2.2.4 Methodology for Equipment Projects

NEMS-PNNL was used to estimate the energy savings associated with the products being developed under BT's Appliances and Emerging Technologies project. The modifications to the NEMS-PNNL input files (RTEKTY.txt for residential, KTECH.wk1 for commercial) for each type of equipment in the Appliances and Emerging Technologies project are described in detail in the project characterizations in Appendix A. The appendix documents EIA's baseline assumptions, the cost and performance attributes of the BT-sponsored technologies and the resulting market shares for these most energy-efficient products.

For a few appliances, some changes were made in EIA's baseline assumptions. Where the original *Annual Energy Outlook 2001* input file does not reflect pending standards that are scheduled to take effect during the analysis period, modifications were made to crudely account for these standards.

One issue related to assessing benefits with the NEMS-PNNL model is the appropriate discount rate to use. If the implied discount rate is too high, discouraging most consumers from choosing the technology, then the logit parameters, Beta1 and Beta2, may be modified. Energy Star or other market transformation projects provide impetus for increased market acceptance of selected technologies. Therefore, when appropriate, parameters are modified to decrease the implied discount rate (i.e., encourage consumers to choose this technology earlier) for the technologies targeted by these projects.

The project's energy savings are therefore calculated as the difference between NEMS-PNNL model runs that 1) include the technology assumed in the *Annual Energy Outlook* base case and 2) substitute the lower-cost units assumed to stem from the BT/WIP project.

2.2.5 GPRA Envelope Calculations Using NEMS-PNNL

The general approach for GPRA envelope calculations using NEMS-PNNL was to simulate the effect of an envelope technology using the FEDS model for many different building types, sizes, vintages, and locations. The heating and cooling loads were calculated 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 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.

FEDS Modeling

To estimate the national impact of introducing a new envelope technology, the impact of that technology must be accurately captured within the buildings where it is likely to be employed. For each technology, the impact was simulated in 3,960 commercial buildings and 1,188 residential buildings representing all combinations of building type, size, vintage, and location (see Table 2-1).

Aggregating FEDS Results for NEMS-PNNL

Because NEMS-PNNL only models one of each building type in each of the nine census regions, the FEDS results needed to be aggregated for input into NEMS-PNNL.

City Weights. The cities shown in Table 2-1 were selected for the FEDS analysis because the weather is characteristic of the climate in the different portions of the census regions. Because NEMS operates on a census region basis, weighted averages of the FEDS results for individual weather cities were produced to represent the loads within a census region. Table 2-2 shows the weights given to each city for each census region.

Table 2-1. Building Simulation Parameters

Building Type	Building Size (ft²)	Vintage (Year Built)	Location
Assembly	4000	1940	Denver, Colorado
Education	7500	1953	Detroit, Michigan
Food Sales	17500	1967	Fresno, California
Food Service	37500	1976	Knoxville, Tennessee
Healthcare	75000	1983	Los Angeles, California
Lodging	125000	2000	Minneapolis, Minnesota
Mercantile and Service			Phoenix, Arizona
Office			Providence, Rhode Island
Warehouse			Seattle, Washington
Other Commercial Buildings			Shreveport, Louisiana
			Tampa, Florida
Single Family	600		
Mobile Home	800		
	1300		
	1800		
	2200		
	3000*		
Multifamily	14309		
	19079		
	31003		
	42927		
	52466		
	71545		

*Single-family and mobile homes are represented by the 600 to 3000 single-family range.

Table 2-2. Weights Given to Each City for Each Census Region (%)

City	New England	Mid Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific
Denver	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.0	2.2
Detroit	0.0	0.0	99.3	60.0	0.0	0.0	0.0	0.0	0.0
Fresno	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.3
Knoxville	0.0	0.0	0.0	0.0	50.7	67.4	13.4	0.0	0.0
Los Angeles	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	71.2
Minneapolis	0.0	0.0	0.7	40.0	0.0	0.0	0.0	0.0	0.0
Phoenix	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	0.0
Providence	100.0	100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Seattle	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.2
Shreveport	0.0	0.0	0.0	0.0	17.7	32.6	80.6	0.0	0.0
Tampa	0.0	0.0	0.0	0.0	31.6	0.0	6.0	0.0	0.0

Floor Area Weights. The fraction of floor space within each size category for each commercial building type was determined using data from 1995 "Commercial Buildings Energy Consumption Survey"[b] and is shown in Table 2-3.

Table 2-3. Percentage of Floor Space in Each Size Category for Each Commercial Building Type (%)

Building Type	Floor Space Size Category— Range and [Modeled Size] ft^2						
	≤5,000 [4,000]	5,001-10,000 [7,500]	10,000-25,000 [17,500]	25,001-50,000 [37,500]	50,001-100,000 [75,000]	>100,000 [125,000]	Total
Assembly	7.9	19.9	23.8	12.3	12.6	23.5	100.0
Education	3.2	5.2	13.5	23.6	22.6	31.8	100.0
Food Sales	36.4	6.4	31.8	19.1	5.1	1.3	100.0
Food Service	40.7	28.8	24.4	5.2	0.6	0.3	100.0
Healthcare	6.5	6.5	10.4	7.5	5.5	63.6	100.0
Lodging	4.1	7.4	20.7	14.2	16.9	36.7	100.0
Mercantile and Service	14.5	17.3	23.1	9.3	10.0	25.7	100.0
Large Office	0.0	0.0	0.0	0.0	27.5	72.5	100.0
Small Office	21.7	18.9	32.7	26.7	0.0	0.0	100.0
Other Buildings	10.8	12.8	19.7	13.0	13.5	30.1	100.0
Warehouse	9.5	11.7	18.0	13.7	13.5	33.5	100.0

Table 2-4 shows the fraction of floor space within each size category for each residential building type (single family, mobile homes, and multifamily). The data for single-family and mobile homes were determined using data from the 1997 "Residential Energy Consumption Survey"[c] and the data for multifamily homes were determined using data from survey and apartment stock data from the National Multi-Housing Council.[d]

[b] Table 9. Where no data were available, expert judgment was used.
[c] Table HC1-4b, single-family, and Table HC1-4b, five or more units.
[d] http://www.nmhc.org/research/default.html.

Table 2-4. Fraction of Floor Space in Each Size Category for Each Residential Type (%)

Building Type	Single-Family Residential Floor Space Size Category—Range and [Modeled Size] ft²					
	≤600 [600]	601-999 [800]	1,000-1,599 [1,300]	1,600-1,999 [1,800]	2,000-2,399 [2,200]	>2,400 [3,000]
Single Family	2.8	14.0	37.0	21.2	11.3	13.7
Mobile Home	15.7	43.8	31.6	7.2	2.2	0.7
Building Type	Multifamily Residential Floor Space Size Category—Range and [Modeled Size] ft²					
	≤14,309 [14,309]	14,310-23,848 [19,079]	23,849-38157 [31,003]	38,158-47,696 [42,927]	47,697-57,236 [52,466]	>57,236 [71, 545]
Multifamily	25.4	49.3	17.9	2.4	0.7	0.2

Vintage Weights. For simplicity, all vintages were given equal weighting.

Market Penetration. The DOE project manager or representative provided market penetration point estimates. For example, the project manager estimated the market penetration to be 15% in 2020 for quick-fill walls in new single-story buildings. Given that 41.8%[e] of commercial buildings are single-story, the resulting market penetration rate is 6.3%. These estimates were then used in the previously developed and documented market penetration model (see Section 3.0, "Diffusion Curves") to estimate the market penetration by year. Pertinent data for the market penetration estimates are provided in the individual project characterizations in Appendix A.

Baseline Assumptions

Consistent with the NEMS-PNNL model, the heating and cooling envelope factors were assumed to be decreasing over time. These changes account for technological improvements over time that would occur without the DOE project. The baseline envelope factors in NEMS-PNNL were modified annually to account for the technological improvements, and the modifiers are calculated using the following equation with 1995 being the base year:

$$BaselineModifier_{new\ buildings} = 0.94\left(\frac{Current\ Year - 1995}{25}\right)$$

Equation 2-45

$$BaselineModifier_{existing\ buildings} = 0.96\left(\frac{Current\ Year - 1995}{25}\right)$$

The project benefits are in addition to the baseline modifier.

[e] 1995 "Commercial Buildings Energy Consumption Survey," Table 9.

Special Considerations

For the electrochromic windows project, 30% of the lighting energy used in commercial buildings is also assumed to be saved (see the project characterization in Appendix A for details). These savings occur at the same rate as the penetration of the electrochromic technology.

Output

The FEDS output for each technology is processed into the following information for direct use by NEMS:

- Census division
- Building type
- Year
- Total heating envelope factor adjustment for new buildings
- Total cooling envelope factor adjustment for new buildings
- Total heating envelope factor adjustment for existing buildings
- Total cooling envelope factor adjustment for existing buildings
- Lighting load adjustment for new buildings
- Lighting load adjustment for existing buildings.

2.3 Spreadsheet Models

Whenever possible, PNNL modeled projects within BESET or NEMS-PNNL to help ensure consistency in baseline inputs and methodology. However, we modeled several projects in spreadsheets because of their unique characteristics. 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. Detailed documentation on each spreadsheet model is contained in the appropriate project characterization in Appendixes A and B. A summary is presented below.

2.3.1 State Energy Project

This project was modeled based on historical information that provides an estimated level of savings per project dollar. Because neither BESET nor NEMS-PNNL is designed for this type of analysis, the project continues to be modeled in a separate spreadsheet. See Appendix B for a detailed explanation of the inputs for and calculation of the State Energy Project benefits.

2.3.2 Weatherization Assistance Project

This project was modeled based on studies that have provided the project with per-household savings estimates. While these inputs may be able to be translated into load reductions and the project run through BESET, such an effort has not been undertaken. The primary barrier to incorporating this project into BESET is that fuel mix for houses in the target market is significantly different between the BESET baseline and historical Weatherization project data. See Appendix B for a detailed explanation of the inputs for and calculation of the Weatherization Assistance Project benefits.

2.3.3 Information Outreach

The estimates for the FY 2004 request were adopted directly from a study commissioned by BT (Messersmith and Azimi 2000). See Appendix B for a detailed explanation of the inputs for and calculation of the Information Outreach benefits.

2.3.4 Building Codes

Building code activities are spread among three decision units, two in BT and one in WIP. However, because of the interrelationships between the three, savings were estimated for the building codes and standards as a whole. Savings estimates were then allocated among the three primary funding sources:

- Building Codes Training and Assistance (within WIP – Gateway Deployment decision unit)
- Residential Building Codes (within BT – Residential Buildings decision unit)
- Commercial Building Codes (within BT – Commercial Buildings Integration decision unit).

The long-term impact of DOE's assistance to code activities is based largely on data developed for internal use in building codes and standards. DOE provides technical support for states seeking to adopt new energy codes, either based on ASHRAE Standard 90.1, "Energy Standards for Buildings, Except Low-Rise Residential Buildings," or the International Energy Conservation Code (previously the Model Energy Code). Several states have self-developed codes that are not supported by building codes and standards and are not counted in the estimates of project impact. See Appendix A for a summary of the inputs for and calculation of the benefits of Building Codes projects.

2.3.5 Lighting R&D: Lighting Controls

PNNL based the estimates of lighting controls savings on an assumed lighting end-use load reduction, penetration rates, and building stock estimates. Energy savings estimates were developed in a spreadsheet model because BESET and NEMS-PNNL are designed to calculate changes in specific lighting technologies and efficacies; not general lighting load reductions. See Appendix A for a detailed explanation of the inputs for and calculation of the lighting controls benefits.

2.3.6 Space Conditioning and Refrigeration R&D: Commercial Refrigeration

The refrigeration savings estimates were based on a report on end-use consumption produced by PNNL, project goals, and other various data sources (Belzer and Wrench 1997). Energy-savings estimates were developed in a spreadsheet model because commercial refrigeration is a service, not a specific piece of equipment, and therefore cannot be modeled in NEMS-PNNL or BESET. See Appendix A for a detailed explanation of the inputs for and calculation of the commercial refrigeration benefits.

2.3.7 Equipment Standards and Analysis: Distribution Transformers

Distribution transformers are part of the electricity distribution system, not the building system. Therefore, transformers cannot be modeled in either NEMS-PNNL or BESET. Savings estimates for a distribution transformer standard were based on a study by Geller and Nadel (1992). See Appendix A for a detailed explanation of the inputs for and calculation of the distribution transformer benefits.

3.0 Technology Diffusion Models – Application to Selected Energy-Efficient Products for Buildings

Diffusion models represent the principal forecasting method for determining potential market penetration for products that have not yet been introduced into the marketplace. Because this situation generally applies to the long-term forecasting horizon of technology assessment models, a means to credibly represent price and policy effects in diffusion models is a key factor in improving the usefulness of market assessment studies. The basic diffusion models assume that the cumulative market penetration follows a characteristic time path (usually in the form of an S-shaped curve).

The dominant type of diffusion model is most likely the mixed-influence model introduced by Frank Bass (1969). The Bass model incorporates parameters that reflect both external (e.g., mass media communication) and internal influences (e.g., word of mouth). In 1998, PNNL conducted a study for DOE/BT to estimate the Bass specification for ten selected energy-efficient building products available in the marketplace today. The results of this work are instrumental in helping to project the likely market pathways of advanced building technologies under development by DOE/BT. This section summarizes the results of that study.

3.1 Scientific and Technical Approach

PNNL conducted a study examining the historical market penetration for ten energy-efficient products related to the buildings sector. Diffusion models were estimated for each product, based on the specification proposed by Bass (1969). The resulting models are intended to help assess technologies supported by BT. This model development and empirical analysis are designed to generate more credible predictions of the adoption process of important energy-efficiency technologies in the buildings sector.

The basic Bass diffusion model, which is possibly the most widely used specification for analyzing market penetration, assumes that the potential market in which the new technology is penetrating is fixed. In reality, the potential market usually is growing in response to a falling price as the manufacturing process and industry structure behind the new technology evolve. This study develops a simple structural model that incorporates these effects and that can be easily estimated from historical data. Given a suitable conceptual model, its parameters can be estimated from data related to several energy technologies.

Most studies of technology adoption have focused either on defining the market potential of the new technology or on the pace at which the technology is adopted. Models that have integrated both aspects generally have not been subjected to historical validation of their underlying parameters. Therefore, in general, little empirical basis exists to suggest which process — diffusion or expanding market potential due to falling costs—might be more influential in driving the penetration of new technologies.

3.2 Background

A report by the Research Triangle Institute for the Electric Power Research Institute (EPRI) (1991) provides a good overview of market penetration approaches. Although the report has a slant toward utilities, much of the discussion applies to all types of energy-saving technologies. The EPRI report clearly distinguishes between two aspects of the process for forecasting market penetration: forecasting market potential and forecasting the rate of market penetration. Forecasting market potential can involve several different concepts of potential, including maximum, technical, and economic potential.

The EPRI report states that the factors affecting the rate of market penetration are predominantly different from factors affecting market potential. For example, comparative advantage—often determined by economic cost—strongly affects market potential. However, comparative advantage doesn't appear to have as strong an effect on the rate of market penetration.

In trying to distinguish the key factors affecting potential vs. penetration, EPRI suggests that market potential is predominantly influenced by the following:

- The market population and demographic trends
- The needs of the market: customer perceptions, attitudes, and beliefs
- Feasibility of the product, which depends on functional characteristics of the product and its economic advantages compared with alternatives.

According to EPRI, the rate of market penetration is predominantly influenced by other factors:

1. Marketing effort, such as promotion, advertising, and product positioning
2. Product characteristics, such as complexity, compatibility, trialability, and observability
3. Characteristics of potential adopters, such as decision-making style, innovativeness, and adoption processes
4. Market characteristics, such as macroeconomic conditions, degree of social interaction among potential adopters, and competitive conditions.

Approaches to predicting the diffusion of a new technology generally fall under the category of judgmental methods or model-based methods. Judgmental methods share the common trait that they don't require mathematical models or computations; they rely implicitly on the experience and perceptions of the forecaster. On the other hand, model-based methods use well-specified algorithms to process and analyze data. Therefore, the model-based methods can provide systematic forecasts of market penetration that are reproducible and amenable to being incorporated into broader integrated models.

Model-based methods can be divided into two major categories: extrapolation models and causal models. Extrapolation methods include the following: 1) naive diffusion process models, 2) moving average, 3) exponential smoothing, 4) Census Bureau X-11, 5) Box-Jenkins, and 6) Multivariate Time Series.

Of the extrapolation methods, the diffusion models represent the principal method for dealing with products that have not yet been introduced. Because this situation generally applies to long-range models, the discussion will be restricted to these models.

Diffusion models assume that the cumulative market penetration follows a characteristic time path (usually in the form of an S-shaped curve). An apt analogy is the spread of contagious disease in a fixed population. Once begun, growth of the disease in the number of infected individuals may follow a stable, predictable path. The time path of the infection in the population depends on the probability of spontaneous infection, the share of infected individuals, and probability of uninfected individuals interacting with individuals already infected. The notion underlying penetration rate models is that information about the new technology—sufficient to induce its adoption—is similar to an infectious disease (although with a much more positive connotation). This model provides the rationale behind the S-shaped ("logistic") penetration curves that are often observed.

3.3 Bass Diffusion Model

Perhaps the dominant type of diffusion model is the mixed-influence model introduced by Bass in the late 1960s. This two-parameter model incorporates parameters that reflect both external and internal influences. The external influence (corresponding to the "spontaneous" infection mentioned above) is exemplified by mass media communication, size of sales force, or other structured channels of information. Spontaneous refers to the adopter not being influenced by previous adopters but by advertising or some other "external change-agent."

In contrast, the internal influence is intended to capture interpersonal communication or word of mouth (i.e., the contagious aspect of the disease analogy above). This also has been termed the "imitative effect"; the decision to adopt is made only after being influenced by prior adopters. The basic specification of the Bass model is as follows:

$$dN(t)/dt = [p + q/M\ N(t)]\ [M - N(t)] \qquad \textit{Equation 3-1}$$

where
- N(t) = cumulative number of adoptions at time *t*
- M = market potential, a constant
- p = the coefficient of innovation or external influence
- q = the coefficient of imitation or internal influence.

Equation 3-1 states that the rate of change in the cumulative number of adopters (dN(t)/dt) is proportional to the difference between the market potential M and the number of previous adopters. The proportionality factor [p + q/M N(t)] can be interpreted as the probability of adoption at time *t*. This probability is composed of two components: p is interpreted as the probability of spontaneous adoption. The term [q/M N(t)] relates to the probability that adoption will be chosen based on the influence of previous adopters. This probability grows as the number of adopters increases.

To simplify the presentation, Equation 3-1 can be reoriented in terms of the fraction of the market *(F)* that is being penetrated rather than the absolute number of adopters. In this case, the market potential can be defined as 1.0. This simplified expression in Equation 3-2 now relates to the change in relative cumulative adoptions:

$$dF(t)/dt = [p + qF(t)]\ [1 - F(t)] \qquad \textit{Equation 3-2}$$

The number of cumulative adoptions at any time, *F(t)*, can be solved by specifying an initial condition that the number of adopters at $t = 0$ is 0. This solution is as follows:

$$F(t) = \frac{1 - \exp(-(p+q)t)}{1 + (q/p)\exp(-(p+q)t)} \qquad \textit{Equation 3-3}$$

The basic diffusion models therefore separate the issue of market penetration rate from market potential. That is why the model in Equation 3-3 can be compared across technologies—the percentage change in the total penetration does not depend on the size of the market but only on the parameters *p* and *q*. This overcomes the limiting assumption mentioned above that the market segments, in unit terms, are fixed through time.

3.4 Estimation Issues

Issues related to the appropriate estimation procedures for the Bass diffusion model spawned a considerable literature. At least four estimation procedures were proposed by various researchers: 1) ordinary least squares (Bass 1969), 2) maximum likelihood estimators (Schmittlein and Mahajan 1982), 3) nonlinear least squares (Srinivasan and Mason 1986) and Jain and Rao (1989), and 4) algebraic estimation (Mahajan and Sharma 1986).

Mahajan, Mason, and Srinivasan (1986) performed a comparative study of estimation procedures using penetration data for seven products. They concluded that the maximum likelihood and nonlinear least squares procedures provided the best predictions of the four procedures considered. Between those two procedures, nonlinear least squares provided slightly better predictive performance and more valid estimates of the standard errors for the parameter estimates.

As preliminary analysis, PNNL looked at three variants of nonlinear least squares model. For the first two variants, the focus is on the number of adopters *(X)* in each period. Taking the differences of Equation 3-3 above and including a separate parameter reflect the total number of adopters (m) results in the following for the first variant:

$$X(i) = \frac{m\left(1-\exp(-(p+q)t_i)\right)}{1+(q/p)\bullet\exp(-(p+q)t_i))} - \frac{m\left(1-\exp(-(p+q)t_{i-1})\right)}{1+(q/p)\bullet\exp(-(p+q)t_{i-1}))} + u_i$$

Equation 3-4

Jain and Rao (1989) suggest that the formulation in Equation 3-4 gives the *ex ante* value for X(i) and does not use the *ex post* information on X(1), X(2), …, X(I-1). In the Bass model, the probability that an individual who has not purchased the product up to period t_{i-1} is given by $[F(t_i) - F(t_{i-1})]/((1 - F(t_{i-1})]$. Thus, the number of adopters in the *i*th time interval is as follows:

$$X_i = (m - N(t_{i-1}))\left(\frac{F(t_i) - F(t_{i-1})}{1 - F(t_{i-1})}\right) + v_i$$

Equation 3-5

where $N(t_{i-1})$ is the cumulative number of adopters up to time t_{i-1}, v_i is the error term, and cumulative distribution function is given by Equation 3-3. This *ex post* estimation procedure proposed by Jain and Rao uses the actual number of cumulative adoptions in the estimation, compared with the *predicted* number in Equation 3-4. Therefore, it is termed the *ex post* estimation in contrast to the *ex ante* estimation.

Mahajan, Mason, and Srinivasan (1986) also point out the possibility of estimating the diffusion curve in level rather than differences form (e.g., cumulative sales rather than annual sales). Thus, the cumulative number of adopters is the dependent variable and the specification becomes the following:

$$N(t_i) = mF(t) = \frac{m\left(1 - \exp(-(p+q)t)\right)}{1 + q/p \bullet \exp(-(p+q)t)} + w_i$$ *Equation 3-6*

As Mahajan, Mason, and Srinivasan (1986) indicate, the errors in Equation 3-6 are likely to be heteroscedastic (i.e., error variance increasing with i) and autocorrelated. Nevertheless, this formulation is somewhat more stable than the differences form and sometimes yields more plausible estimates.

3.5 Results

The results of estimating the Bass (1969) diffusion model for ten energy-related technologies are described below. The technologies were placed into four separate categories: 1) lighting, 2) HVAC and refrigeration (HVAC/R), 3) envelope, and 4) other. Table 3-1 summarizes the technologies for which Bass diffusion models were estimated.

Table 3-1. Summaries of Technologies Analyzed

Technology	Start Year	End Year	Market Definition
Lighting			
Electronic Ballast	1986	1997	Corrected Power-Factor Ballasts
Compact Fluorescent	1986	1994	Incandescent, 15-150 Watt
T-8 Lamps	1986	1994	Fluorescent lamps, >30 Watt
HVAC and Refrigeration			
Electric Heat Pump	1970	1995	Residential Furnaces
Flame Retention Burner	1975	1987	All Oil Burners
Condensing Gas Furnace	1982	1997	Gas Furnaces
Advanced Compressor	1982	1995	No. of Supermarkets
Room Air Conditioners	1949	1961	No. of Households
Envelope Technologies			
Low-E Window	1983	1996	Residential Windows
Other			
DOE-2 Bldg Model[f]	1984	1994	Commercial Buildings Designed

In most of the cases, the technology was not assumed to ultimately capture all of the market, as defined in the third column of the table. The maximum market potential was determined judgmentally, on the basis of inspection of the data or from other sources.

Table 3-2 presents the results of the estimation work. The parameter sets labeled in bold are those judged as the most preferred, based on the reasonableness of the estimates and statistical significance. While estimates were developed based on both annual adoptions and cumulative adoptions, at this point, estimates based on annual adoptions have been

[f] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

used. The annual adoption rates are expressed as a fraction of the total potential market and the maximum fraction of the total market potential is expressed exogenously. The first and third groups of estimates reflect an effort to allow the data to suggest the maximum market potential (m rather than m^*).

Examination of the estimated coefficients indicates that the estimates of the external influence parameter are much more variable than those for the internal influence parameter. One of the lowest values of the internal influence coefficient is found for CFLs; this coefficient reflects the lamps extremely slow initial penetration into the market. In addition to the lamp's high initial price, Haddad (1994) suggests that industrial organization, retail incentives, and social convention are additional reasons for the atypically slow adoption of this technology. On the other extreme is the flame retention oil burner, whose adoption was accelerated by the increase in oil prices during the Iranian revolution in the late 1970s. In spite of these extremes, the simple average internal influence coefficient of 0.38 is the same as the average for 213 technologies as reported by Sultan, Farley, and Lehmann (1990). In that study, the average external influence was 0.03 compared with an average 0.018 for the ten energy-related technologies.

Table 3-2. Diffusion Curve Parameter Results

Product	Annual Sales						Cumulative Sales					
	p	q	m	p	q	m*	p	q	m	p	q	m*
Electronic Ballasts	0.0054 (0.6)	0.6489 (2.5)	0.4815 (3.4)	**0.0138** (1.1)	**0.3729** (3.3)	**0.6**	0.0037 (2.1)	0.7006 7.3)	0.4627 (19.5)	0.0092 (3.3)	439 9.3)	0.6
Compact Fluorescent				**0.0075**	**0.071**	**0.50**						
T-8 Lamps				**0.0041**	**0.326**	**0.80**						
Electric Heat Pump				**0.0118**	**0.459**	**0.23**	0.0054 (1.6)	0.6228 5.9)	0.2169 (43.9)	0.0112 (2.2)	0.4588 (6.3)	0.23
Flame Retention Burner				**0.0039**	**0.655**	**1.0**	<0.001 (0.3)	1.774 (3.7)	0.8143 (23.9)	0.0040 (1.1)	0.655 (4.6)	1.0
Condensing Gas Furnace				**0.070** (1.8)	**0.071** (0.8)	**0.3**	0.0782 (3.6)	0.2082 (1.8)	0.238 (14.7)	0.0881 (6.1)	0.0240 (0.6)	0.3
Room Air Conditioners				**0.0072**	**0.423**	**0.33**						
Advanced Compressors	.0232 (9.6)	0.2788 (11.3)	0.9514 (21.3)	**0.0247** (11.2)	**0.2483** (22.1)	**1.0**	0.0242 (31.4)	0.2633 (20.5)	0.9801 (39.8)			
Low-E Windows	0.0562 (8.2)	0.2936 (7.3)	0.3663 (18.3)	**0.0577** (9.6)	**0.2729** (14.3)	**0.37**				0.0565 (25.0)	0.2819 (27.3)	0.37
DOE-2 Building Model	0.00001 (0.5)	1.18 (4.8)	0.279 (6.4)	**0.0005**	**0.656**	**0.50**						

p represents the coefficient of innovation (external influence)
q represents the coefficient of imitation (internal influence)
m is the maximum market potential suggested by the data
m* is an assumed value taken from graphical output
The first and third groups of estimates reflect the results when all three parameters (p, q, and m) are estimated based on the data.
The second and fourth groups of estimates reflect the results when two parameters (p and q) are estimated, with m (as m*) set based on graphical output
Values in parentheses are t-values, where available.

3.5.1 Lighting Technologies

As Table 3-1 outlines, the generic lighting diffusion curve is based on the market penetration of the electronic ballast, compact fluorescent, and T-8 lamp technologies. Tables 3-3 through 3-5 and Figures 3-1 through 3-3 detail the penetration of these technologies and chart the predicted penetration rates. To develop a generic lighting curve, the three lighting technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the three curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic lighting curve are 0.005 (external, or p) and 0.25 (internal, or q). Figure 3-4 charts the diffusion curves for the three technologies and the generic lighting curve.

Table 3-3. Ballast Shipments and Penetration of Electronic Ballasts

Year	Corrected Power-Factor Type (magnetic) (million)	Electronic Type (million)	Total Ballast Shipments (million)	Penetration of Electronic type (fraction)
1986	52.04	0.43	52.47	0.008
1987	54.75	0.65	55.40	0.012
1988	56.80	1.06	57.86	0.018
1989	58.27	1.43	59.70	0.024
1990	55.81	3.00	58.81	0.051
1991	55.47	8.34	63.81	0.131
1992	55.38	13.29	68.67	0.194
1993	54.79	24.49	79.28	0.309
1994	55.99	24.61	80.60	0.305
1995	47.65	32.90	80.55	0.408
1996	42.84	30.34	73.18	0.415
1997	42.89	36.54	79.43	0.460
1998	42.58	39.84	82.42	0.483
1999	41.44	41.63	83.07	0.501
2000	37.54	49.32	86.86	0.568
Source: Bureau of the Census, Current Industrial Reports [MQ36C(97)-5; MQ335C (01)-5.				

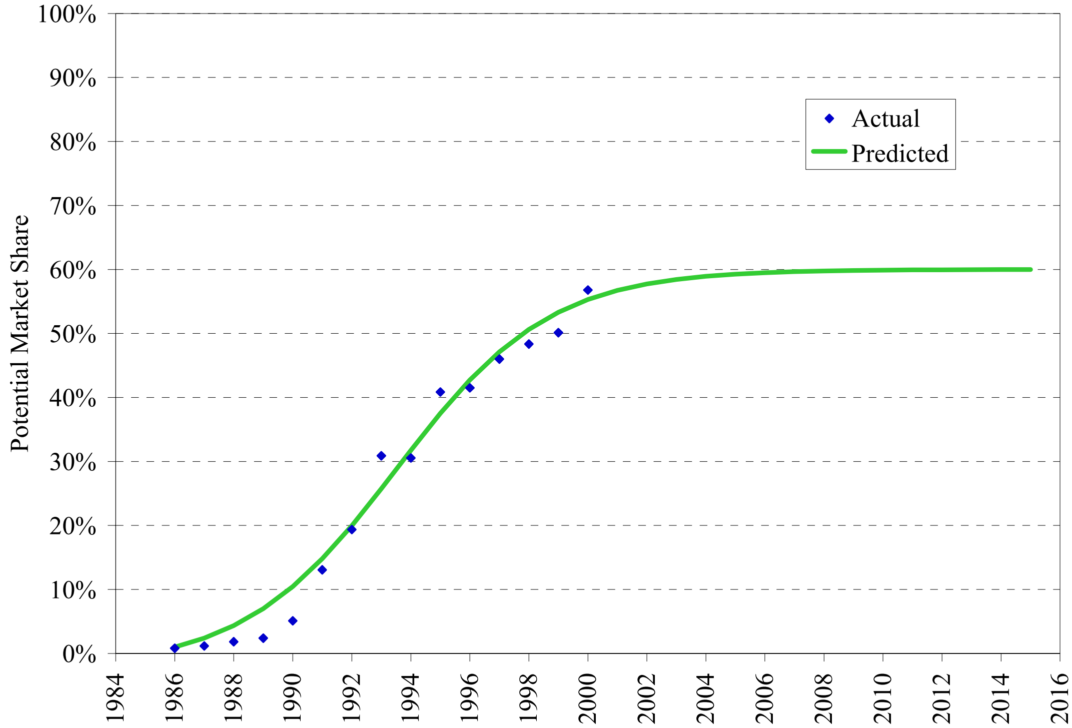

Figure 3-1. Actual and Predicted Penetration Rates: Electronic Ballasts

Table 3-4. Total Fluorescent Tube and T-8 Tube Shipments

Year	Conventional Fluorescent (1)			Linear T-8 (million)	Data Source for T-8
	Low-Power (million)(2)	High-Power (million)	Total (million)(3)		
1985	45	255	300	0	estimate
1986	45	270	315	0.5	estimate
1987	45.7	287	332.7	1	estimate
1988	50	300	350	2	EPRI (4)
1989	55	315	370	3.1	EPRI
1990	62	332.8	394.8	5.7	EPRI
1991	69.3	353.1	422.4	15	estimate
1992	70.3	367.4	437.7	27.7	CIR (5)
1993	71.5	389.9	461.4	43.8	CIR
1994	78.4	399.7	478.1	56.1	CIR

(1) "Conventional Fluorescent" corresponds to the Census Bureau's category of "Other Fluorsecent Lamps"; excludes slimline, circular, and high-output 800 milliamp or more. Includes T-8 Lamps.

(2) Low-power is defined as 40 watts or less prior to 1992, 30 watts from 1992 through 1994. No adjustment was made to achieve definitional consistency.

(3) Values for conventional fluorescent are estimated for 1985, 1986, 1988 and 1989.

(4) EPRI 1992.

(5) CIR: Current Industrial Report, MQ36B.

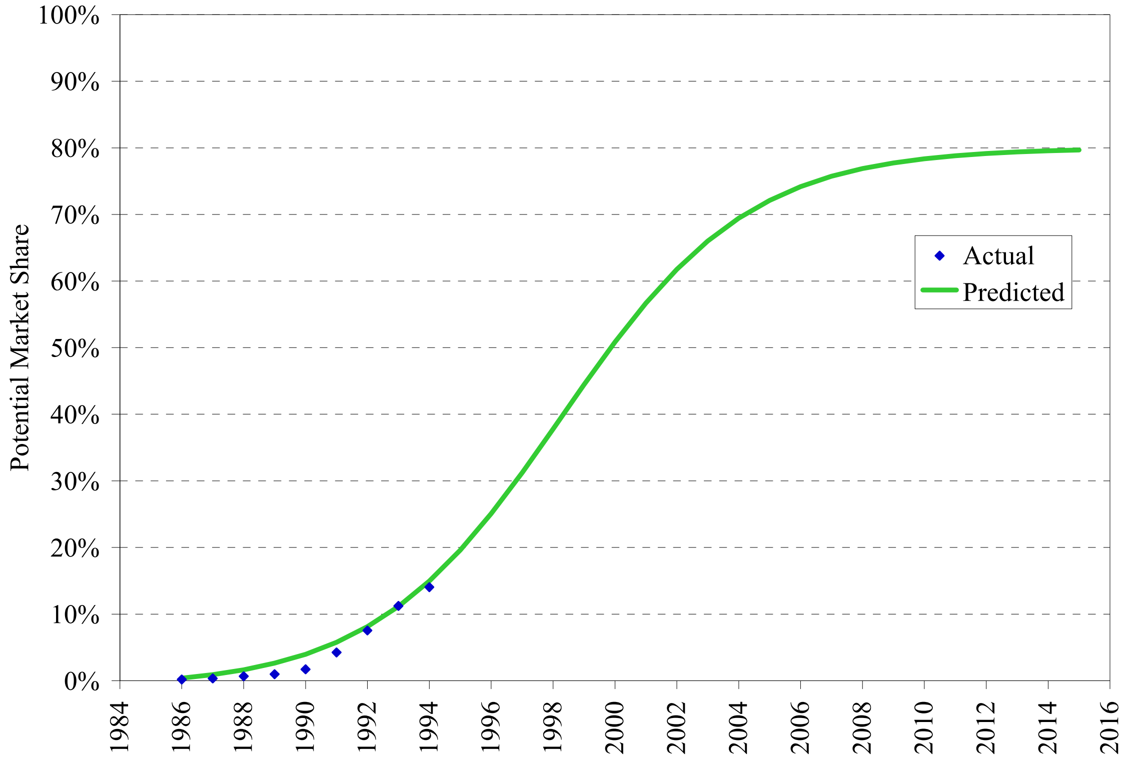

Figure 3-2. Actual and Predicted Penetration Rates: T-8 Lamps

Table 3-5. Shipments and Penetration of CFLs

Year	Incandes. 15-150 watt (million)	CFLs (million)	Total (million)	Market Penetration	Data Sources	
					Incandes.	CFL
1986	800.0	2.0	802.0	0.0025	estimate	estimate
1987	800.0	4.0	804.0	0.0050	estimate	estimate
1988	800.0	9.9	809.9	0.0122	estimate	EPRI
1989	810.7	11.6	822.3	0.0141	CIR*	EPRI
1990	798.6	16.7	815.3	0.0205	CIR	EPRI
1991	783.0	25.2	808.2	0.0312	CIR	estimate
1992	795.5	30.4	825.9	0.0368	CIR	CIR
1993	847.1	33.4	880.5	0.0379	CIR	CIR
1994	818.8	35.8	854.6	0.0419	CIR	CIR

Source: EPRI 1992.
*CIR: Current Industrial Reports, Bureau of the Census, MQ36B, various issues.

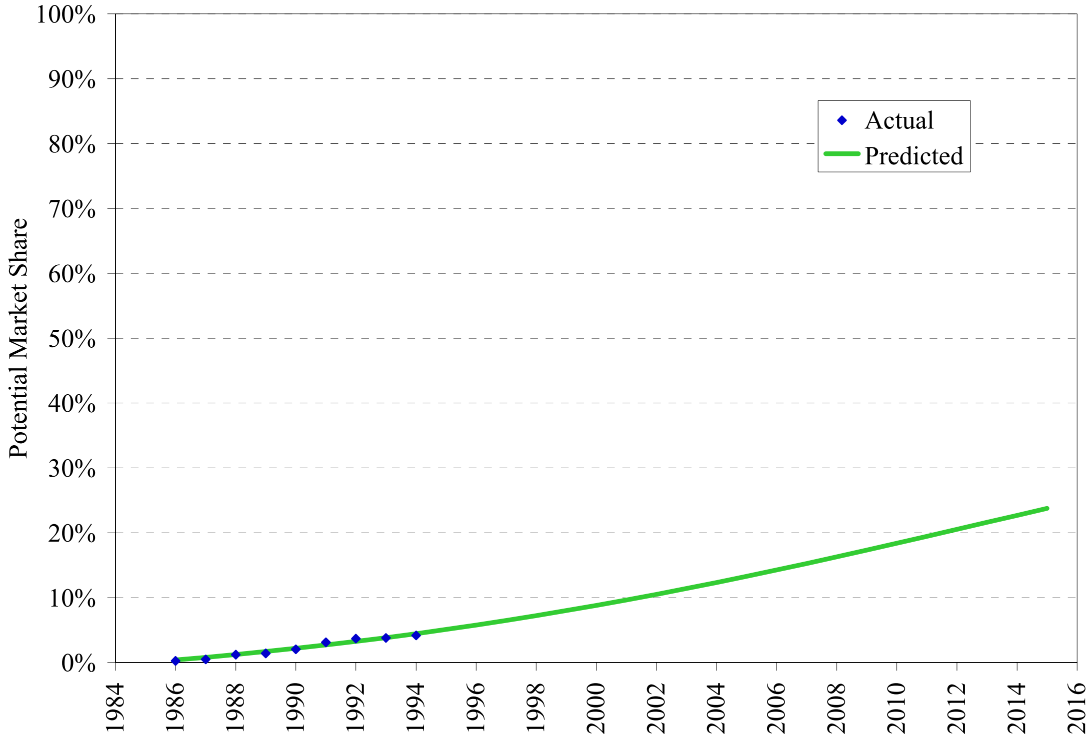

Figure 3-3. Actual and Predicted Penetration Rates: CFLs

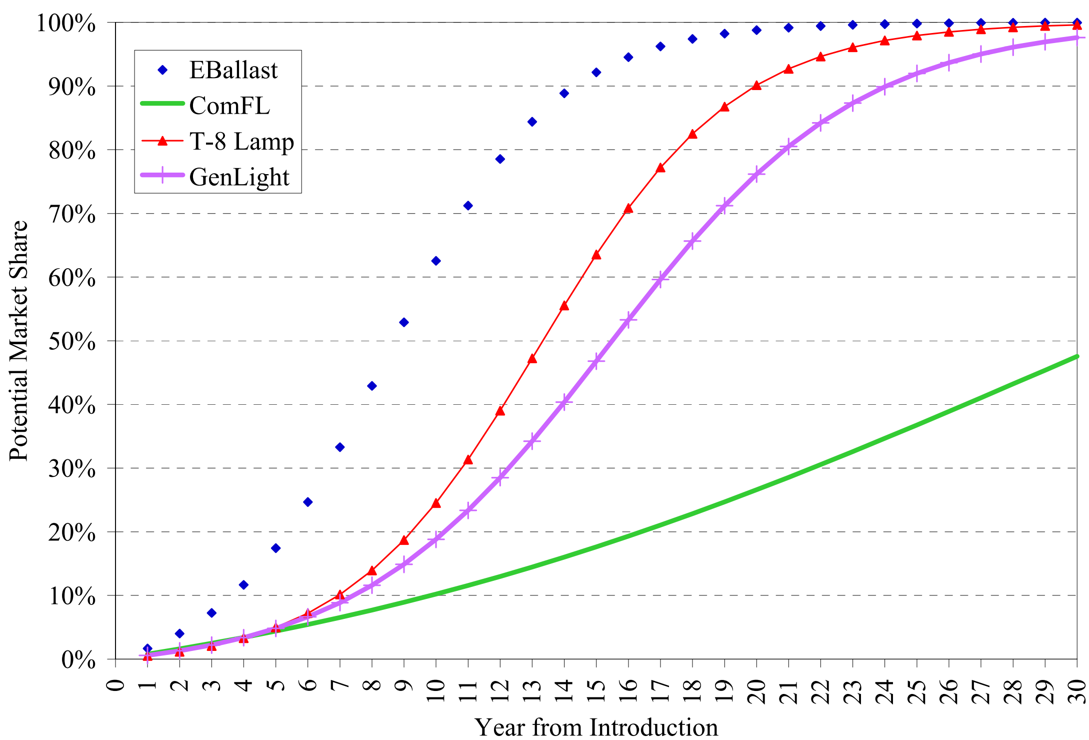

Figure 3-4. Generic Lighting Diffusion Curve Compared With Other Lighting Technology Curves (Normalized to m* = 1.0)

3.5.2 HVAC Technologies

As Table 3-1 outlines, the generic HVAC diffusion curve is based on the market penetration of the electric heat pump, flame retention burner, condensing gas furnace, and room air conditioners technologies. Tables 3-6 through 3-9 and Figures 3-5 through 3-8 detail the penetration of these technologies and the predicted penetration rates. To develop a generic HVAC curve, the four HVAC technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the four curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic HVAC curve are 0.02 (external, or p) and 0.3 (internal, or q). Figure 3-9 charts the diffusion curves for the four technologies and the generic HVAC curve.

Table 3-6. Advanced Electric Heat Pump Shipments and Penetration

Year	Gas Furnaces (thousands)	Electric Furnaces (thousands)	Split System Heat Pumps (thousands)	Total (thousands)	HP Market Penetration (fraction)
1970	1471.2	105.3	33.6	1610.1	0.021
1971	1795.2	193.8	26.6	2015.6	0.013
1972	2066.2	288.5	32.3	2387.0	0.014
1973	1719.5	370.2	43.9	2133.6	0.021
1974	1476.3	406.8	56.6	1939.7	0.029
1975	1185.8	252.3	92.8	1530.9	0.061
1976	1544.4	338.9	202.0	2085.3	0.097
1977	1508.1	283.6	356.8	2148.5	0.166
1978	1636.1	360.0	420.8	2416.9	0.174
1979	1862.6	360.0	407.6	2630.2	0.155
1980	1445.7	360.0	323.4	2129.1	0.152
1981	1416.7	360.0	390.4	2167.1	0.180
1982	1155.6	300.0	300.9	1756.5	0.171
1983	1661.8	360.0	509.6	2531.4	0.201
1984	1849.2	360.0	603.1	2812.3	0.214
1985	1822.3	370.0	665.2	2857.5	0.233
1986	2104.8	382.6	728.3	3215.7	0.226
1987	2072.9	375.1	754.6	3202.6	0.236
1988	2092.2	293.1	680.9	3066.2	0.222
1989	2162.2	298.2	690.0	3150.4	0.219
1990	1950.5	280.0	667.4	2897.9	0.230
1991	2056.7	245.2	637.1	2939.0	0.217
1992	2106.9	290.2	670.0	3067.1	0.218
1993	2584.6	348.5	747.5	3680.6	0.203
1994	2696.8	400.8	857.6	3955.2	0.217
1995	2601.0	402.0	866.6	3869.6	0.224

Sources: For gas furnaces the source is the Census of Manufactures, 1972 and 1977; PNNL estimates are for the intervening years; and the Gas Appliance Manufacturers Association (GAMA) is for years 1986-1995.

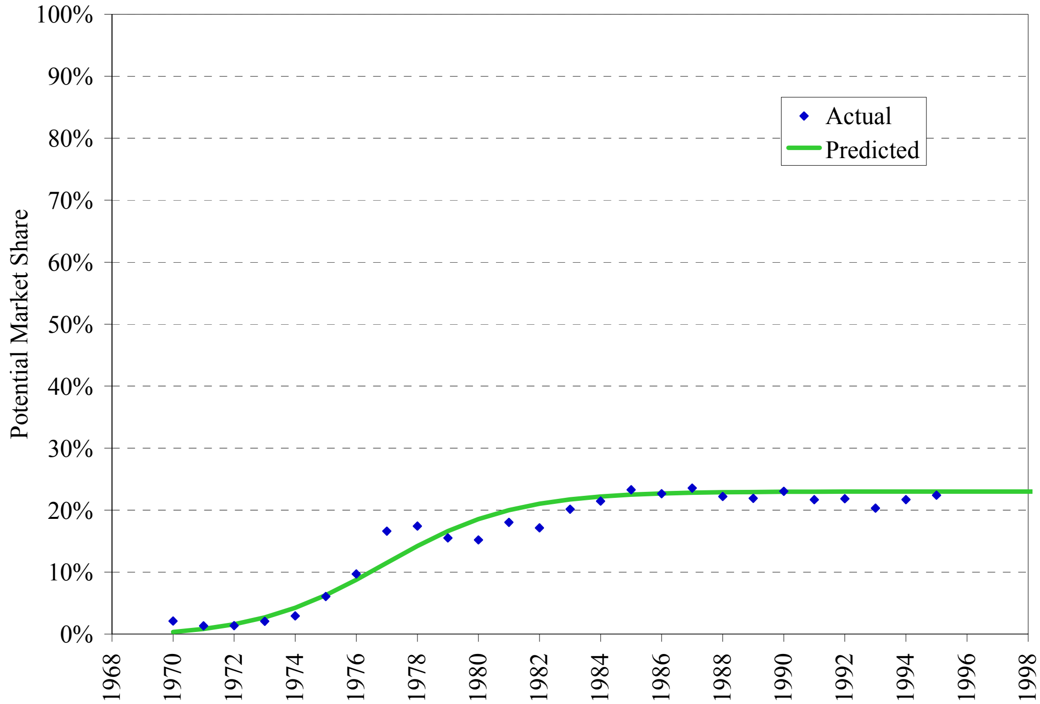

Figure 3-5. Actual and Predicted Market Penetration: Electric Heat Pumps

Table 3-7. Sales and Market Penetration of Flame Retention Head Oil Burners (FRHOBs)

	Annual Oil Burner Sales(1) (thousand)	Cumulative FRHOB Sales(2) (thousand)	Annual FRHOB Sales(3) (thousand)	FRHOB Market Share(4) (fraction)
1975	750	20	20	0.027
1976	750	50	30	0.040
1977	749	70	20	0.027
1978	777	100	30	0.039
1979	735	125	25	0.034
1980	585	250	125	0.214
1981	606	400	150	0.248
1982	522	800	400	0.766
1983	512	1200	400	0.781
1984	510	1600	400	0.784
1985	536	2000	400	0.746
1986	555	2450	450	0.811
1987	577	2950	500	0.867

(1) Annual oil burner sales data from 1977-1987 were obtained through a telephone interview with Don Farrell, using data files maintained by *Fuel Oil and Oil Heat Magazine*. Data for 1975 and 1976 are PNNL estimates.
(2) Cumulative sales for FRHOBs were obtained from ORNL report by Brown et al. (1989), Figure 4.3, p. 55.
(3) Annual FRHOB sales data were estimated as the difference in cumulative sales in Column
(4) Market share of FRHOB is the ratio of FRHOB sales over total burner sales.

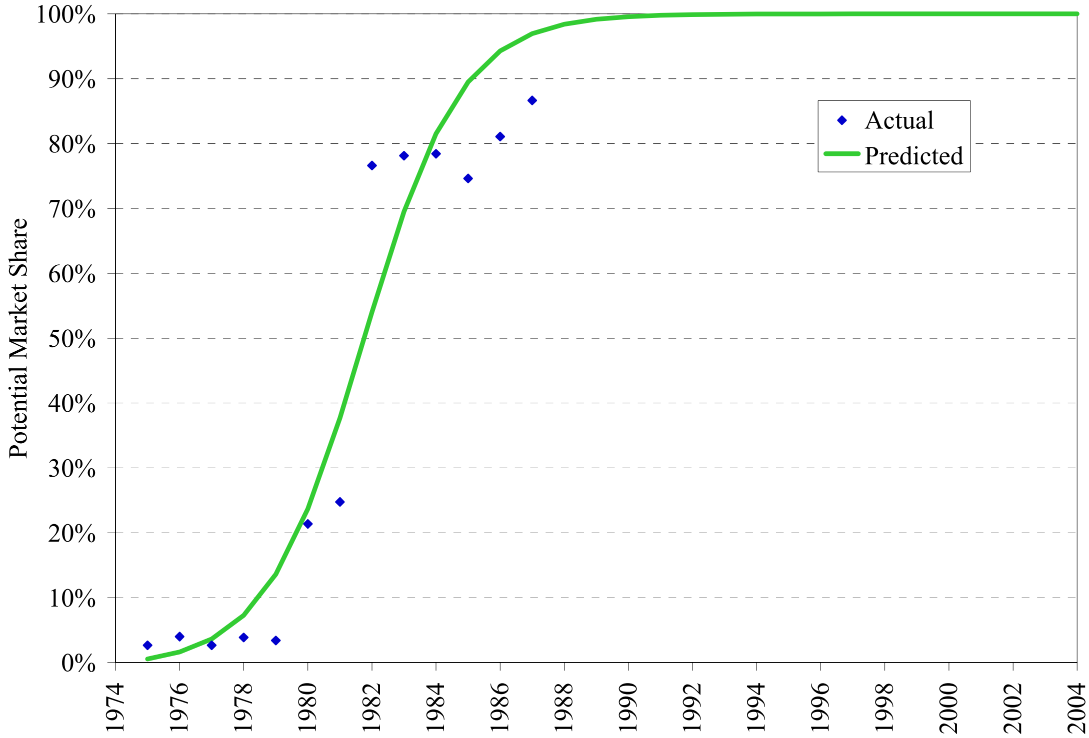

Figure 3-6. Actual and Predicted Market Penetration Rates: Flame Retention Oil Burners

Table 3-8. Market Penetration of High Efficiency Gas Furnaces

Year	Market Share	Source
1981	0.005	PNNL Estimate
1982	0.010	PNNL Estimate
1983	0.040	PNNL Estimate
1984	0.111	GAMA
1985	0.123	GAMA
1986	0.158	GAMA
1987	0.160	PNNL Estimate
1988	0.165	PNNL Estimate
1989	0.170	PNNL Estimate
1990	0.175	GAMA
1991	0.205	GAMA
1992	0.210	PNNL Estimate
1993	0.210	PNNL Estimate
1994	0.214	GAMA
1995	0.223	GAMA
1996	0.235	GAMA
1997	0.253	GAMA
1998	0.240	PNNL Estimate
1999	0.233	GAMA
2000	0.236	GAMA
2001	0.279	GAMA

Note: For 1984-1987, the fraction relates to annual fuel utilization efficiency (AFUE) of 86% and greater. For subsequent periods, the fraction relates to furnaces with AFUE of 86% and greater. Because of some changes in the AFUE testing procedures, these fractions are roughly comparable.

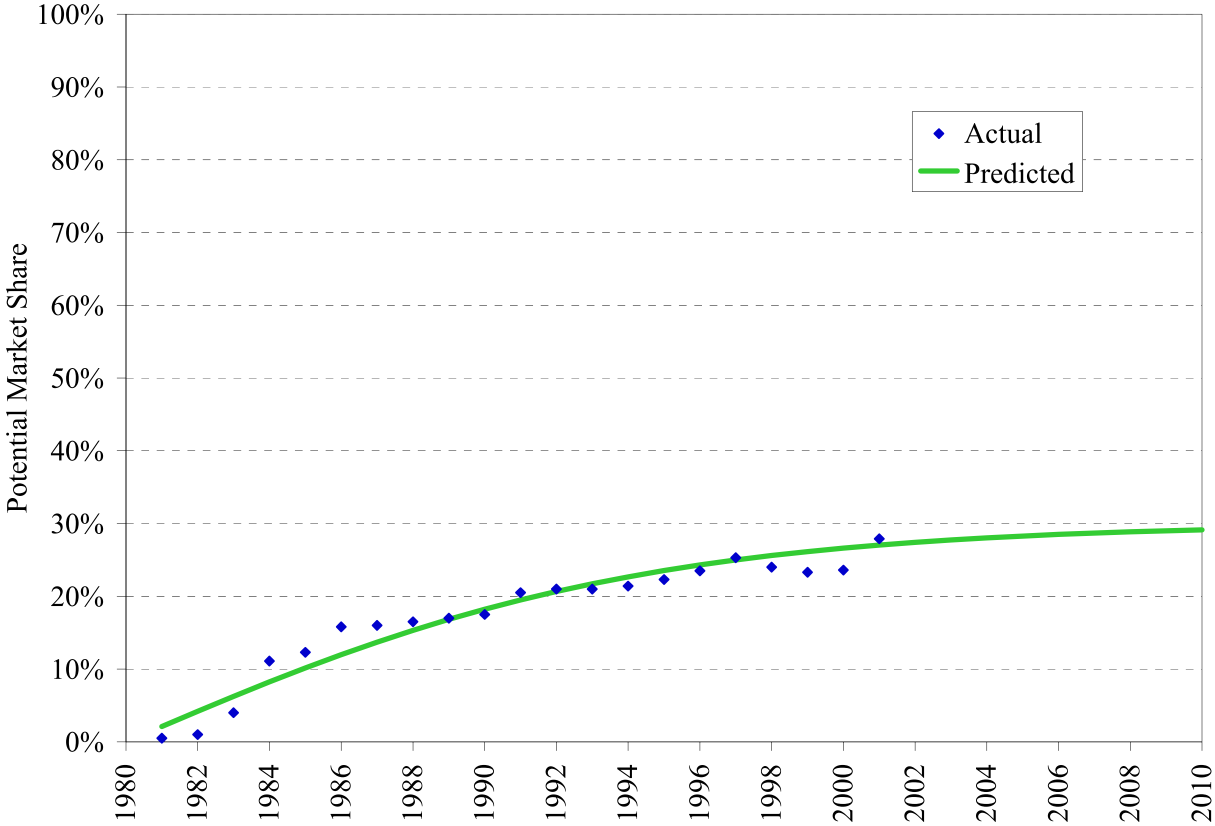

Figure 3-7. Actual and Predicted Market Penetration for Condensing Gas Furnaces

Table 3-9. Room Air Conditioner Sales

Year	Sales (thousands)
1949	96
1950	195
1951	238
1952	380
1953	1045
1954	1230
1955	1267
1956	1828
1957	1586
1958	1673
1959	1800
1960	1580
1961	1500
Source: Mahajan, Mason, and Srinivasan (1986).	

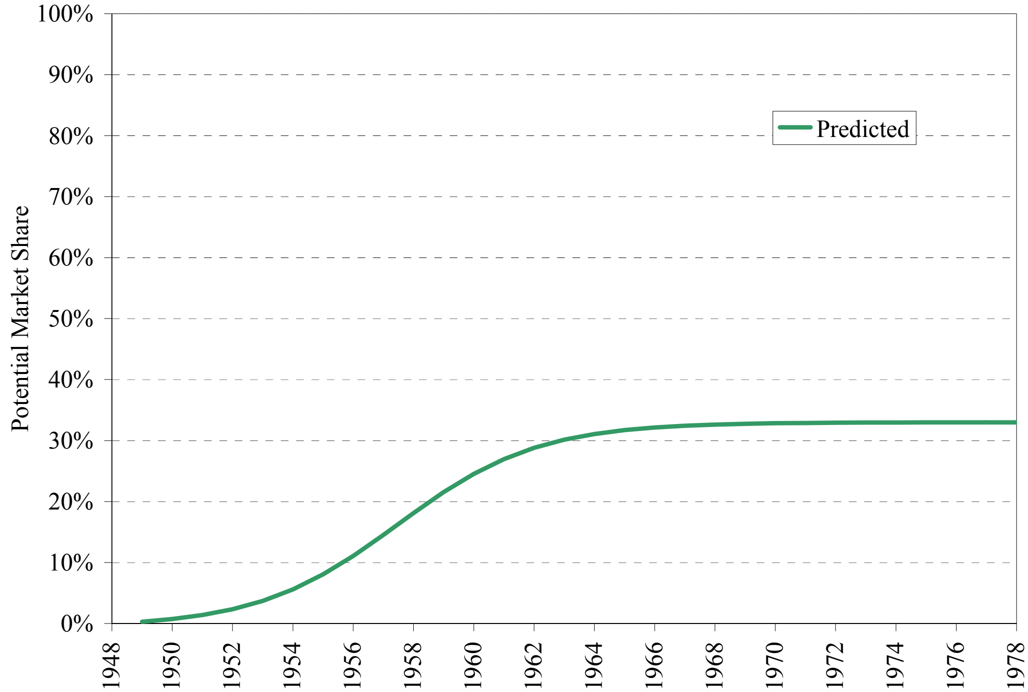

Figure 3-8. Predicted Market Penetration of Room Air Conditioners

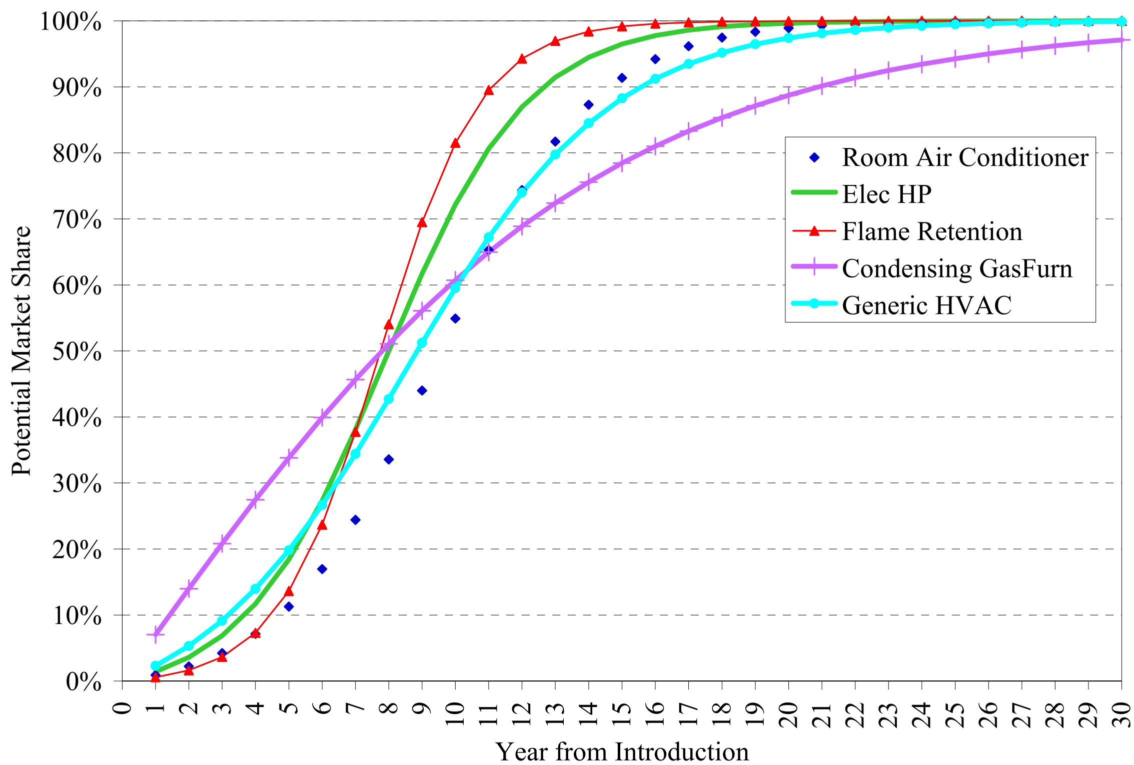

Figure 3-9. Generic HVAC Diffusion Curve Compared With Other HVAC Technology Curves (Normalized to m* = 1.0)

3.5.3 Envelope and Other Technologies

Three other technologies were also studied and form the basis for the generic envelope and other technologies diffusion curve. The generic envelope/other diffusion curve is based on the market penetration of the advanced compressor, low-E window, and DOE-2 technologies.[g] Tables 3-10 through 3-12 and Figures 3-10 through 3-12 detail the penetration of these technologies and chart the predicted penetration rates. To develop a generic envelope/other curve, the three technology curves were normalized by setting m* (the maximum market potential) to 1.0. By plotting the three curves using the normalized market potential, a generic curve was specified by visual determination. The resulting parameters for the generic envelope/other curve are 0.01 (external, or p) and 0.3 (internal, or q). Figure 3-13 charts the diffusion curves for the three technologies and the generic Envelope/Other curve.

Table 3-10. Market Penetration of High-Efficiency Refrigerator Compressors for Supermarkets

Year	Market Penetration (fraction)
1982	0.03
1983	0.06
1984	0.11
1985	0.16
1986	0.21
1987	0.27
1988	0.34
1989	0.41
1990	0.50
1991	0.58
1992	0.65
1993	0.71
1994	0.76
1995	0.80
Source: Geller and McGaraghan 1995, Figure 3.	

[g] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact. The inclusion of the normalized DOE-2 curve into the development of the generic envelope/other curve does cause the generic curve to be less steep than if it were to be fit between the Advanced Compressor and Low-E window curves.

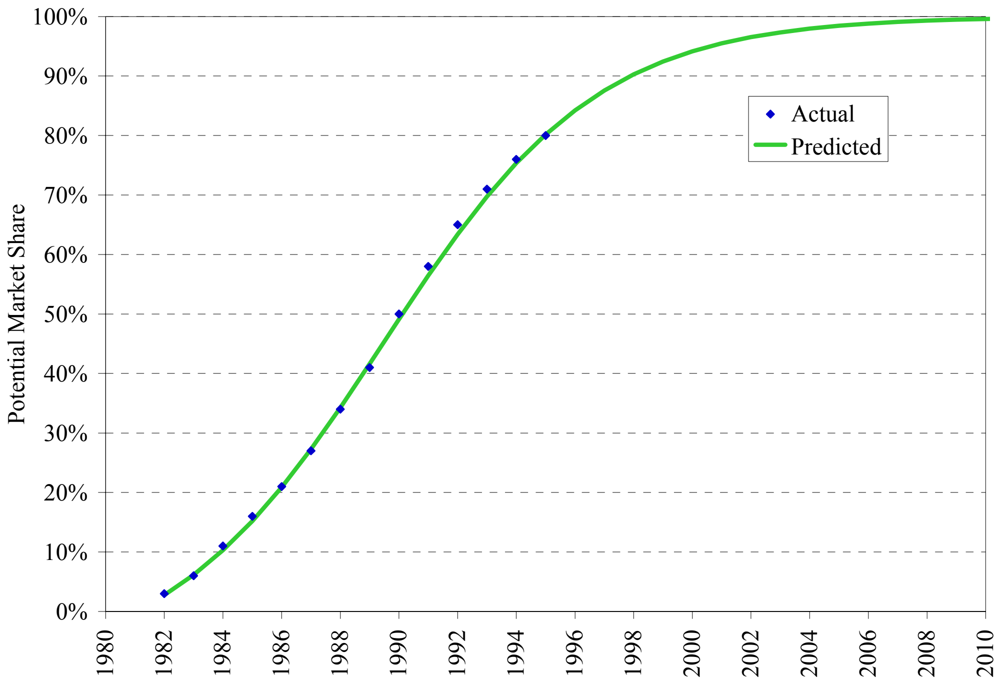

Figure 3-10. Actual and Predicted Market Penetration Rates: Advanced Refrigeration Compressors for Supermarkets

Table 3-11. Market Penetration of Low-E Residential Windows

Year	Market Penetration (fraction)	Source
1983	0.01	PNNL Estimate(1)
1984	0.02	PNNL Estimate(1)
1985	0.05	PNNL Estimate(1)
1986	0.12	ACEEE(2)
1987	0.16	PNNL Estimate(3)
1988	0.20	PNNL Estimate(3)
1989	0.23	PNNL Estimate(3)
1990	0.26	PNNL Estimate(3)
1991	0.28	AAMA(4)
1992	0.30	PNNL Estimate
1993	0.32	AAMA(4)
1994	0.34	PNNL Estimate
1995	0.35	AAMA(4)
1996	0.35	LBNL(5)

(1) Accelerating penetration consistent with 12% share in ACEEE 1996.
(2) Geller and McGaraghan 1996, Figure 1.
(3) Interpolated in a manner to show declining rates of increase.
(4) Study of U.S. Market for Windows and Doors, American Architectural Manufacturers Association (AAMA), 1996.
(5) Personal communication with D. Arasteh, LBNL, on June 11, 1998.

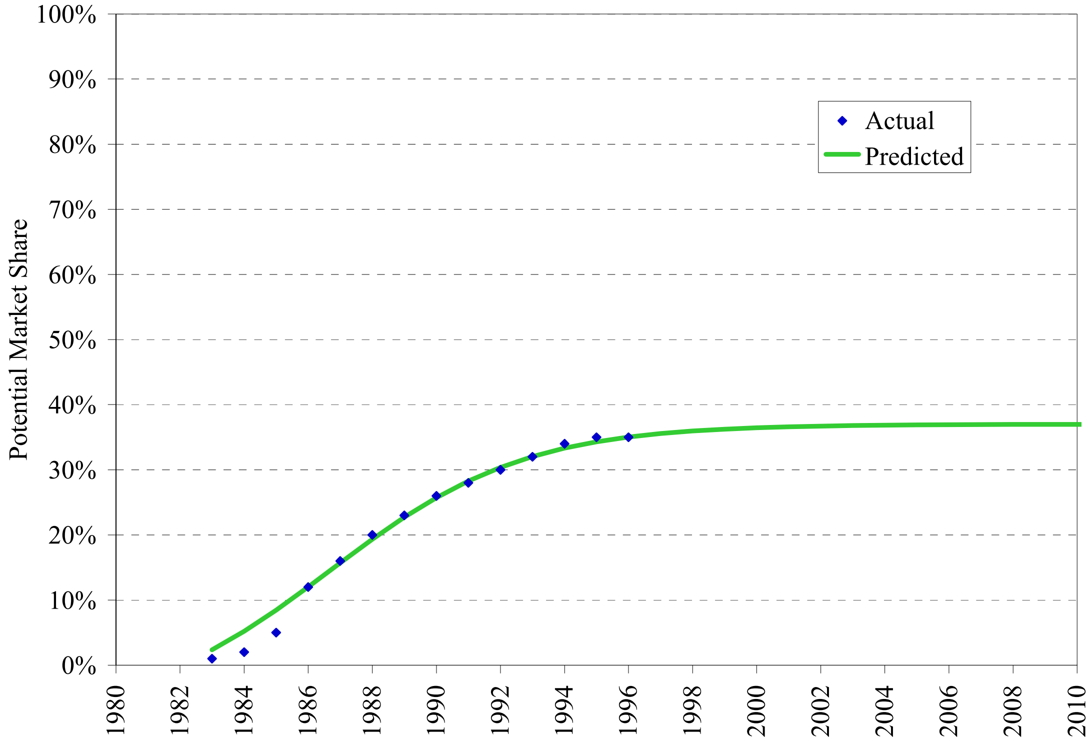

Figure 3-11. Actual and Predicted Market Penetration Rates: Residential Low-E Windows

Table 3-12. Market Penetration of DOE-2 Used as a Design Tool [h]

Year	Market Penetration (fraction)
1984	0.006
1985	0.013
1986	0.019
1987	0.025
1988	0.031
1989	0.038
1990	0.044
1991	0.050
1992	0.119
1993	0.189
1994	0.258
Source: Data from Dru Crawley, U.S. Department of Energy, Spreadsheet dated April 17, 1996.	

[h] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

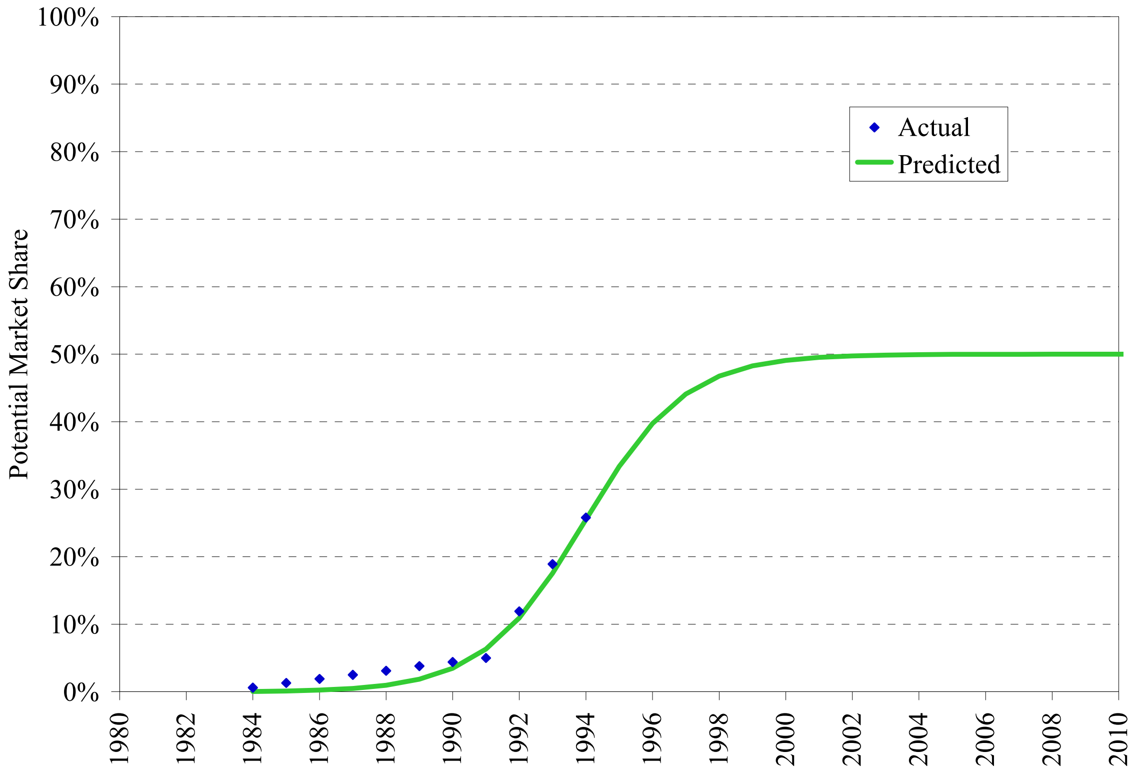

Figure 3-12. Market Penetration of DOE-2 in Use as a Design Tool [i]

[i] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact.

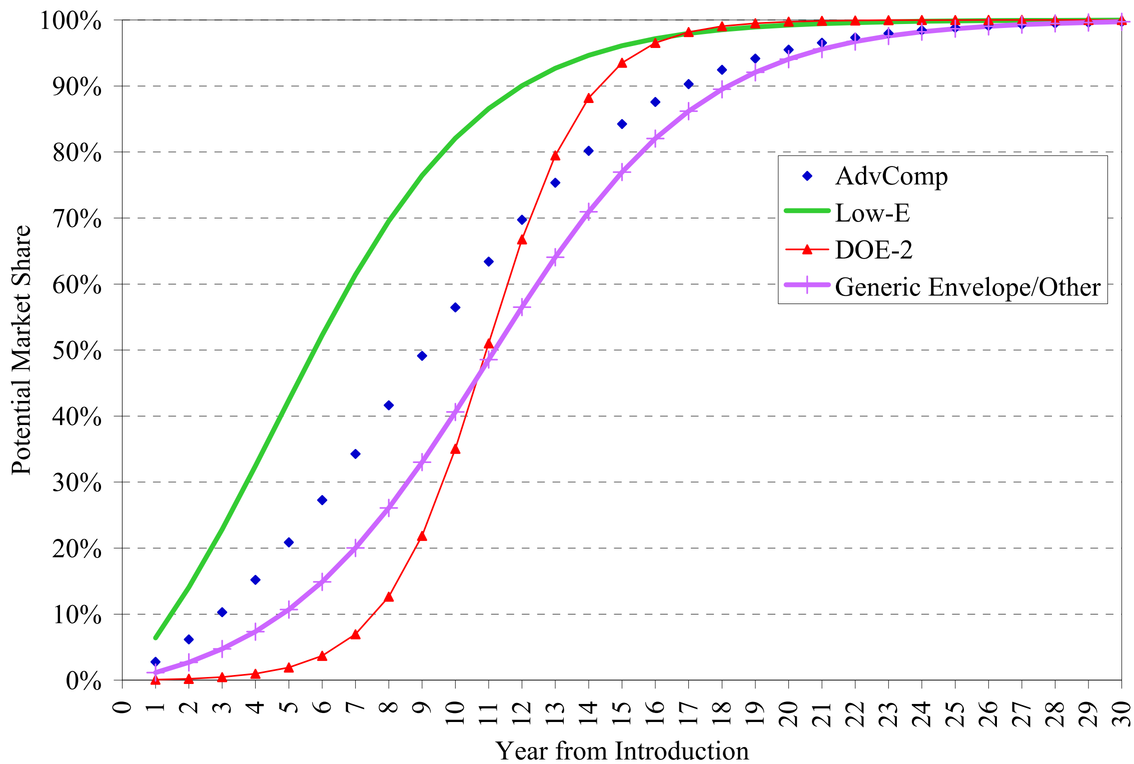

Figure 3-13. Generic Envelope/Other Diffusion Curve Compared With Other Technology Curves (Normalized to m* = 1.0) [j]

3.6 Use of the Generic Curves within the GPRA Analysis

PNNL used the generic diffusion curves to generate market penetration estimates for BT/WIP projects that do not have a forecast of annual sales targets. We created a simple penetration model spreadsheet to generate BT/WIP project-specific diffusion curves for input to the BESET model. Within the spreadsheet, the user specifies the year of market introduction for the project, the expected maximum market potential in 2020, and the technology classification that best resembles the project (lighting, HVAC, envelope, or other project).

Some of the estimated BT/WIP project diffusion curves stray from the generic classifications, depending on their individual characteristics, and use one of the specific technology parameter sets in Table 3-2.

[j] Our diffusion curve work was performed prior to the NRC 2001 report, and while the authors recognize that very serious concerns were raised regarding the actual penetration of DOE-2 into the building design marketplace, we have included it here, due in large measure to the absence of any alternative sources of statistically significant information regarding building design tool use. In future GPRA work, PNNL will endeavor to locate more robust estimates of market impact. The inclusion of the normalized DOE-2 curve into the development of the generic envelope/other curve does cause the generic curve to be less steep than if it were to be fit between the Advanced Compressor and Low-E window curves.

Each of the diffusion curves developed as input to the BESET model are contained within the specific project characterizations in Appendix A (BT projects) and Appendix B (WIP projects).

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Data Bucket Report for Commercial Building Codes Program
Data Bucket Report for Commercial Building Integration R&D Program
Data Bucket Report for Energy Star Program
Data Bucket Report for Information Outreach Program
Data Bucket Report for Lighting R&D Program
Data Bucket Report for Rebuild America Program
Data Bucket Report for Residential Building R&D Program
Data Bucket Report for Space Conditioning and Refrigeration: Refrigeration Program
Data Bucket Report for State Formula Grants Program
Data Bucket Report for Weatherization Assistance Program

5.0 List of Terms

AFUE	annual fuel utilization efficiency
AAMA	American Architectural Manufacturers Association
BESET	Building Energy Savings Estimation Tool
BT	Office of Building Technologies Programs
BTS	Office of Building Technology, State and Community Programs
CBECS	Commercial Buildings Energy Consumption Survey
CFL	compact fluorescent lights
CO	carbon monoxide
COP	coefficient of performance
DOE	U.S. Department of Energy
EER	energy efficiency ratio
EERE	Office of Energy Efficiency and Renewable Energy
EIA	Energy Information Administration
EPAct	Energy Policy Act of 1992
EPRI	Electric Power Research Institute
EREC	Energy Efficiency and Renewable Energy Clearinghouse
FEDS	Facility Energy Decision System
FRHOB	flame retention head oil burners
GAMA	Gas Appliance Manufacturers Association
GPRA	Government Performance and Results Act of 1993
IECC	International Energy Conservation Code
LBNL	Lawrence Berkeley National Laboratory
LTS	Lincoln Technical Services
MMBtu	million Btu
MMTCE	million metric tons carbon equivalent
MMton	million metric tons
NEMS	National Energy Modeling System
NO_x	nitrous oxides
ORNL	Oak Ridge National Laboratory
PBFA	Office of Planning, Budget Formulation, and Analysis
PM	particulate matter
PNNL	Pacific Northwest National Laboratory
QBtu	quadrillion Btu
R&D	research and development
RECS	Residential Energy Consumption Survey
SEER	seasonal energy efficiency ratio
SO_2	sulfur dioxide
TBtu	trillion Btu
VOC	volatile organic compound
WIP	Office of Weatherization and Intergovernmental Programs

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Appendix A – Building Technologies Program

This appendix describes the results of the forecasted energy savings, consumer cost savings, and carbon benefits for each of the 25 BT projects (for 2004, 2005, 2010, and 2020). Tables show forecasted benefits up to the year 2030 for all projects and decision units. The BT projects are also characterized in this appendix.

A.1 Energy Savings Analysis by Decision Unit

Decision unit benefits 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 FY 2004 on, so the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from CFLs is the energy saved in 2010 only, from all buildings that have had such lights installed between 2004 and 2010. Table A-1.1 summarizes the primary energy savings, the carbon equivalent reductions, and the consumer cost savings for the four BT decision units.

Table A-1.1 Summary of Benefits: Analyses of BT Projects

Decision Unit	FY 2004 Budget Request (million $)	2004	2005	2010	2020
Primary Energy Savings (TBtu/Yr)					
Residential Buildings Integration	19.2	0.6	1.6	18.3	119.4
Commercial Buildings Integration	5.0	0.0	0.5	11.8	185.6
Emerging Technologies	21.8	19.7	38.2	234.0	901.1
Equipment Standards and Analysis	9.0	0.0	3.4	91.4	383.2
Totals		20.3	43.8	355.4	1589.4
Carbon Equivalent Emission Reductions (MMTCE/Yr)					
Residential Buildings Integration	19.2	0.0	0.0	0.3	2.1
Commercial Buildings Integration	5.0	0.0	0.0	0.2	3.4
Emerging Technologies	21.8	0.3	0.7	4.4	16.2
Equipment Standards and Analysis	9.0	0.0	0.1	1.8	7.2
Totals		0.4	0.8	6.8	28.9
Consumer Cost Savings (Million $/yr)					
Residential Buildings Integration	19.2	4.0	11.0	137.0	972.0
Commercial Buildings Integration	5.0	0.0	3.0	78.0	1397.0
Emerging Technologies	21.8	135.0	258.0	1737.0	7347.0
Equipment Standards and Analysis	9.0	0.0	22.0	606.0	2938.0
Totals		139.0	294.0	2558.0	12,654.0

Total primary energy savings for all BT projects are estimated to reach 0.35 QBtu by year 2010 and 1.6 QBtu by year 2020. Figure A-1.1 charts annual energy savings for all projects for all years from FY 2004 to FY 2020. Roughly half of the savings are generated in the residential sector and half in the commercial sector.

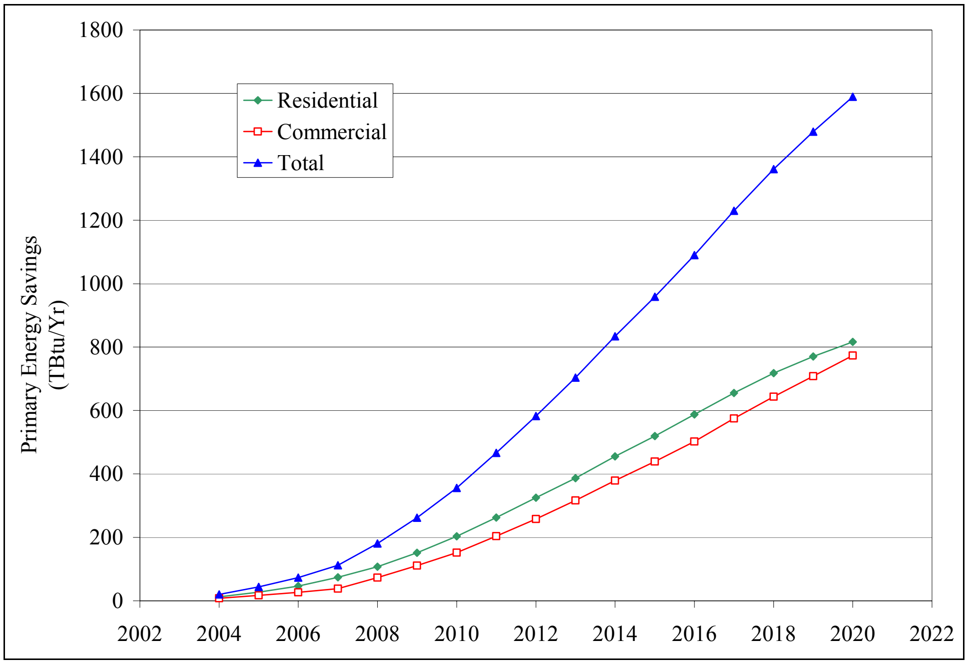

Figure A-1.1 BT Primary Energy Savings by Sector Through FY 2020

Figure A-1.2 compares the BT and WIP primary energy savings projections with the *Annual Energy Outlook 2002* building energy consumption forecasts. The FY 2004 estimates only include savings for projects that are included in the FY 2004 BT and WIP funding request. Some activities funded in previous years may contribute to total BT and WIP future energy savings but are *not* in the FY 2004 request. For example, a project that supports a rulemaking that is completed in FY 2003 would not be included in the FY 2004 request; however, this project would produce energy savings in future years.

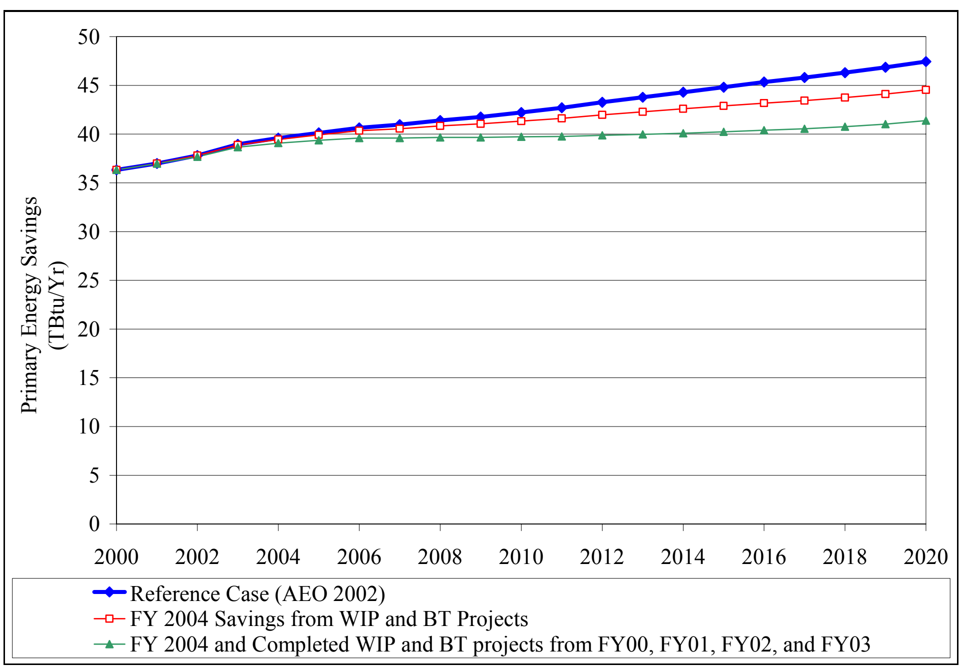

Figure A-1.2 Building Energy Consumption With and Without BT/WIP Savings

Figure A-1.2 shows savings for FY 2004 projects and projects that have been retired since FY 2000 but have future energy savings. The BT and WIP project savings projections are charted relative to the building energy consumption forecasts generated by *Annual Energy Outlook 2002*. Figure A-1.2 shows that if the forecasted savings generated by BT and WIP projects are subtracted from forecasted total building energy use, total primary building energy use remains relatively flat through 2020.

Of all BT energy savings (in year 2020), projects included in the Emerging Technologies decision unit generate over half of the total savings (see Figure A-1.3). This decision unit targets efficiency improvements for specific heating, cooling, and lighting equipment as well as shell (e.g., windows, roofs, and insulation) efficiency improvements. The Emerging Technologies decision unit makes up ~40% of the overall BT program FY 2004 budget request. The Equipment Standards decision unit makes up ~24% of the total savings while accounting for 16% of the total budget request.

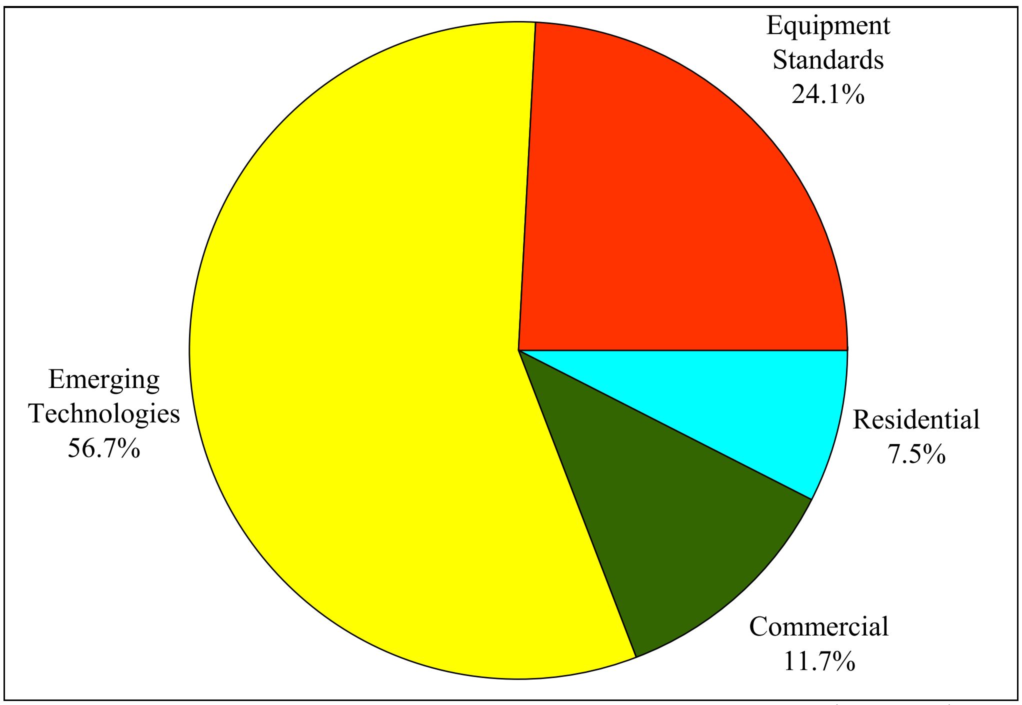

Figure A-1.3 Primary Energy Savings by Decision Unit (for 2020)

In terms of energy savings per budget dollar, the decision units within BT have fairly similar ratios (e.g., savings are proportional to budget), except for the Residential Buildings decision unit, which has a slightly lower savings-to-budget ratio than the other decision units. Projects such as Building America and Zero Energy Buildings (both contained in the Residential Buildings decision unit), which more narrowly target specific building types, tend to have relatively lower penetration rates and lower ratios of savings to budget dollar. The building codes projects (found in the Residential and Commercial Buildings decision units) have a relatively high ratio of savings to budget dollar. The buildings codes projects benefit from having high penetration rates because these standards become regulatory mandates when adopted by states. Similarly, the equipment manufacturing standards (contained in the Equipment Standards decision unit) resulting from the Energy Policy Act of 1992 (EPAct) will be a mandatory standard, which means the efficiency improvements produced by the covered equipment will have a relatively high market penetration. Figure A-1.4 charts the FY 2004 final budget request and the energy savings of each decision unit.

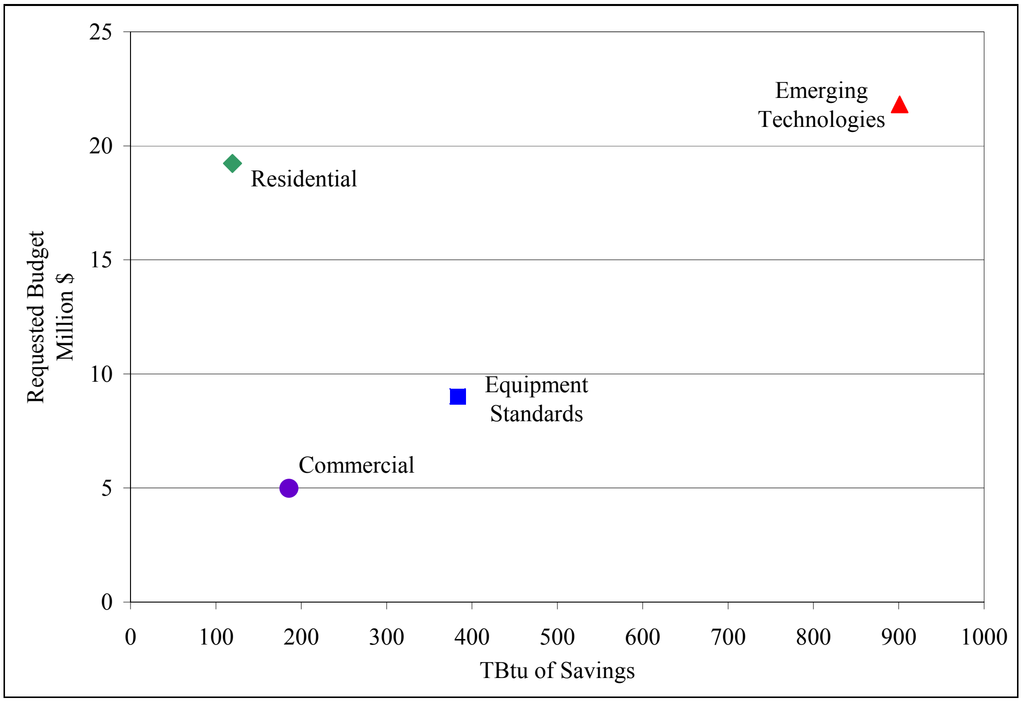

Figure A-1.4 Budget and Energy Savings Scatter Plot for BT Decision Unit

A.2 FY 2004 GPRA Metrics for BT Based on FY 2004 BT Budget Request

This section summarizes the GPRA metrics benefits estimates produced for BT and submitted to EERE's Office of Planning, Budget Formulation, and Analysis (PBFA) as part of the FY 2004 GPRA metrics effort. These estimates were produced in conjunction with the final BT FY 2004 budget request (dated February 3, 2003) and represent the expected benefits as a result of project activities funded under the FY 2004 budget request. Benefits resulting from funding in years before FY 2004 are not included, and benefits accruing from future funding are included in the estimates.

A.2.1 Scope of Analysis

The benefits estimates are developed based on a series of assumptions developed project-by-project and documented in sections A.3 through A.15. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because BT projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects and that the cost and performance characteristics improve as projects mature or as they near commercialization.

A.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics[a]

Energy savings estimates are reported to PBFA at a decision unit level; however, this section explains changes that arise at the individual project/technology level. While estimates at this level are not reported to PBFA as part of the GPRA metrics, they provide a useful planning tool for BT and variations should be understood.

Overall, the estimated energy savings from BT projects through 2020 are lower than those associated with the FY 2003 request. The FY 2003 estimate of 0.42 QBtu in 2010 falls to 0.37 quadrillion Btu (QBtu) for the FY 2004 request, and the FY 2003 estimate of 1.67 QBtu in 2020 falls to 1.59 QBtu for the FY 2004 request.

The discussion has been divided into five categories relative to primary energy savings in the year 2020:

1. Projects characterized in FY 2003 but not in FY 2004
2. Projects that have not changed significantly between FY 2003 and FY 2004
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004
4. Projects that have changed more than 50% between FY 2003 and FY 2004
5. Projects characterized in FY 2004 but not in FY 2003.

Projects that fall into the first category have been completed or terminated and are not in the FY 2004 request. Projects that fall into the fifth category were not characterized in the FY 2003 metrics either because they were new to the FY 2004 request or because not enough information was available about them in FY 2003 to characterize them.

In general, projects are included in GPRA based on whether they are a line item in the initial budget request with a specific funding allocation. Occasionally, projects do not appear as a line item in the initial funding request but do appear in the final request. These projects are characterized within GPRA metrics only if enough information is available to characterize the project in a short period of time. For projects covering a suite of technologies, the technologies characterized are based on discussions with the project manager. This suite of technologies may change from year to year as the project manager changes focus. The suite of technologies is meant to represent the project, not to capture all funded activities. Any other projects not mentioned did not result in any change in out-year primary energy savings estimates. The impact of these categories of projects is shown in Table A-2.1.

[a] FY 2003 GPRA metrics were based on BESET Run 4N; FY 2004 GPRA metrics were based on BESET Run 5.

Table A-2.1 Impact of Projects

Changes by Category	Year 2020 (TBtu)
FY 2003 Estimate	1,672
Less	
1. Projects characterized in FY 2003 but not in FY 2004	-132
Plus	
2. Projects that have not changed significantly between FY 2003 and FY 2004	25
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004	-26
4. Projects that have changed more than 50% between FY 2003 and FY 2004	29
5. Projects characterized in FY 2004 but not in FY 2003	72
Equals	
FY 2004 Estimate	**1,589**

- Projects characterized in FY 2003 but not in FY 2004 – One project fits this category: Lighting R&D – Two-Photon Phosphors. In FY 2004, the two-photon phosphors activity was not funded in anticipation of the Next Generation Lighting Initiative.

- Projects that have not changed significantly between FY 2003 and FY 2004 – The modeling methods or characterizations for eight projects or technologies did not change significantly between FY 2003 and FY 2004:

  – Residential Technology R&D
  – Commercial Technology R&D
  – Next Generation Lighting (formerly Solid State Lighting)
  – Space Conditioning and Refrigeration R&D: Residential HVAC Distribution System
  – Space Conditioning and Refrigeration R&D: Advanced Electric Heat Pump Water Heater
  – Space Conditioning and Refrigeration R&D: Refrigerant Meter
  – Analysis Tools and Design Strategies
  – Equipment Standards and Analysis: EPAct Standards.

- Projects that have changed 25% to 50% between FY 2003 and FY 2004 – One project fits this category: Residential Building Codes. The energy savings from this project decreased almost 26 TBtu in 2020 because the planned code development efforts were re-evaluated.

- Projects that have changed more than 50% between FY 2003 and FY 2004 – Four projects fit this category:

  – Commercial Building Codes: The energy savings from this project decreased ~55 TBtu in 2020 because the planned code development efforts were re-evaluated.

  – Space Conditioning and Refrigeration R&D: Commercial Refrigeration. The energy savings from this project increased ~12 TBtu in 2020 because of increases in the baseline building stock forecast.

- Appliances & Emerging Technologies R&D: Recessed Can Lights. The energy savings from this project increased by almost 30 TBtu because of an algorithm correction that more correctly models "new" buildings. This technology was assumed to be applicable only to new construction.

- Standards: Distribution Transformers. The energy savings from this project increased by ~42 TBtu because of increases in the base transformer sales forecast.

- Projects characterized in FY 2004 but not in FY 2003 – a new initiative was added to the BT budget request for FY 2004 – Zero Energy Buildings. The Zero Energy Buildings project is expected to result in almost 72 TBtu of savings annually by 2020.

A.2.3 FY 2004 GPRA Metrics – Detailed Tables

Tables A-2.2 through A-2.19 are included here to show forecasted benefits up to the year 2030 for all projects and decision units. The benefit estimates available include:

- Energy Savings Benefits Tables (TBtu per year)
  - Total Primary Energy Savings
  - Total Site Energy Savings
  - Primary Electricity savings
  - Primary Non-Electric Savings
  - Site Electricity Savings
  - Site Natural Gas Savings
  - Site Oil Savings.

- Environmental Benefits Tables (million metric tons per year)
  - Carbon Equivalent Emissions Reductions
  - SO_2 Emissions Reductions
  - NO_X Emissions Reductions
  - CO Emissions Reductions
  - Particulate matter (PM) Emissions Reductions
  - Volatile Organic VOC Emissions Reductions.

- Financial Benefits Tables (million $ per year)
  - Consumer Cost Savings
  - Non-Energy Cost Savings
  - Incremental Investment.

- Employment and Income Impacts (from ImBuild)
  - Employment (thousand jobs per year)
  - Income (million $ per year).

In all benefits tables, project benefits are reported annually. The energy savings estimate for 2010 represents energy saved in 2010 only. These are not cumulative benefits estimates. However, the energy saved in 2010 is a function of all project activities from FY 2004 on, so that the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from recessed can lights (within Appliances and Emerging

Technologies R&D project) is the energy saved in 2010 only, from all buildings that have had such lights installed any time between 2004 and 2010.

Reductions in emissions from BT projects are calculated from GPRA metrics estimates of energy savings by fuel type, multiplied by emissions coefficients provided by PBFA for use in GPRA metrics.

The consumer cost savings, as defined in EERE GPRA guidance, represent the monetary value of the energy saving estimates. These estimates are calculated from GPRA metrics estimates of energy savings by sector and fuel type, multiplied by energy price forecasts provided by PBFA for use in GPRA metrics.

BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.2. Primary Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.6**	**1.6**	**3.5**	**5.7**	**8.9**	**18.3**	**58.5**	**119.4**	**200.8**	**302.6**
Research & Development (Building America)	0.3	0.9	2.0	3.3	5.0	9.1	17.2	21.0	23.2	25.4
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.8	9.9	26.8	45.3	64.8
Zero Energy Buildings	0.3	0.8	1.5	2.5	3.8	8.3	31.4	71.6	132.3	212.5
2 Commercial Buildings Integration	**0.0**	**0.5**	**1.0**	**1.5**	**2.8**	**11.8**	**102.7**	**185.6**	**266.1**	**345.7**
Research & Development	0.0	0.5	1.0	1.5	2.8	10.9	88.4	140.6	178.6	215.2
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.9	14.4	45.0	87.5	130.5
3 Emerging Technologies	**19.7**	**38.2**	**61.9**	**94.8**	**132.5**	**234.0**	**558.0**	**901.1**	**1,124.3**	**1,269.2**
Lighting R&D: Controls	1.3	2.5	4.0	6.1	8.6	14.7	30.8	39.7	50.3	59.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.6	97.9	161.5
Refrigeration R&D: Res. HVAC Dist. System	1.6	3.9	7.1	11.6	17.7	36.1	104.5	113.5	61.6	38.8
Refrigeration R&D: Adv. Elec HPWH	0.0	0.1	0.3	0.7	1.4	3.6	21.5	54.4	68.8	43.8
Refrigeration R&D: Commercial Refrigeration	0.4	0.9	1.7	2.9	4.4	9.2	29.6	34.6	16.2	3.1
Refrigeration R&D: Refrigerant Meter	0.0	0.3	0.9	2.0	3.7	9.8	53.4	132.9	162.8	95.8
Appliances & Emerging Tech R&D: HPWH	2.1	3.4	5.3	8.3	12.2	24.6	55.5	65.2	79.0	94.5
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.7	1.2	1.6	1.9	2.3	3.0	3.4	4.0	4.6
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.1	0.3	0.8	2.0	3.8	9.7	27.9	33.8	33.8	33.9
Appliances & Emerging Tech R&D: R-Lamp	2.5	6.6	12.1	19.4	25.2	33.5	3.1	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	6.0	8.6	11.3	14.6	17.4	23.8	38.2	56.2	78.2	102.5
Window Technologies: Superwindows	5.5	9.6	14.3	20.4	27.8	46.9	122.1	194.2	274.3	361.7
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.2	0.3	0.5	2.3	5.1	8.3	11.8
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	4.4	14.3	24.5	35.1
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.8	4.3	8.2	22.2	42.7	65.7	91.0
Analysis Tools and Design	0.1	0.3	0.6	1.1	1.6	3.7	18.6	41.4	68.9	96.1
4 Equipment Standards and Analysis	**0.0**	**3.4**	**6.8**	**10.4**	**36.2**	**91.4**	**239.3**	**383.2**	**445.8**	**511.2**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.4	30.9	45.7	62.1
Standards: EPAct Standards	0.0	3.4	6.8	10.4	26.8	60.2	153.8	241.5	278.1	315.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	9.4	26.5	68.1	110.9	122.0	134.1
Building Technologies Total	**20.3**	**43.8**	**73.1**	**112.4**	**180.4**	**355.4**	**958.6**	**1,589.4**	**2,037.0**	**2,428.7**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM

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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.3. Site Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.4**	**1.0**	**2.2**	**3.7**	**5.8**	**12.4**	**41.8**	**86.9**	**144.9**	**216.5**
Research & Development (Building America)	0.2	0.6	1.4	2.3	3.5	6.6	12.8	15.8	17.4	19.1
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.7	8.6	23.4	39.2	55.8
Zero Energy Buildings	0.2	0.4	0.8	1.4	2.3	5.1	20.4	47.7	88.2	141.6
2 Commercial Buildings Integration	**0.0**	**0.3**	**0.6**	**0.8**	**1.7**	**7.0**	**62.5**	**109.2**	**148.3**	**186.7**
Research & Development	0.0	0.3	0.6	0.8	1.7	6.7	56.7	90.5	111.9	132.5
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.3	5.8	18.8	36.4	54.2
3 Emerging Technologies	**9.0**	**18.1**	**30.5**	**47.1**	**68.4**	**130.6**	**346.5**	**555.7**	**686.4**	**796.9**
Lighting R&D: Controls	0.4	0.8	1.3	2.1	3.0	5.6	12.7	17.2	21.8	25.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	42.4	69.9
Refrigeration R&D: Res. HVAC Dist. System	1.1	2.7	5.0	8.2	12.7	26.8	80.0	88.1	47.0	28.5
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.1	0.2	0.5	1.4	8.9	23.5	29.8	19.0
Refrigeration R&D: Commercial Refrigeration	0.1	0.3	0.6	1.1	1.7	3.9	13.5	16.5	7.7	1.5
Refrigeration R&D: Refrigerant Meter	0.0	0.1	0.3	0.7	1.3	3.7	22.1	57.5	70.5	41.5
Appliances & Emerging Tech R&D: HPWH	0.7	1.1	1.8	2.8	4.3	9.3	22.9	28.2	34.2	40.9
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.7	2.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.1	0.3	0.7	1.3	3.7	11.4	14.5	14.6	14.6
Appliances & Emerging Tech R&D: R-Lamp	0.8	2.1	4.1	6.5	8.8	12.7	1.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	1.2	1.9	2.7	3.6	4.6	7.3	13.8	22.4	32.0	42.5
Window Technologies: Superwindows	4.4	7.6	11.4	16.2	22.3	38.1	100.5	160.3	224.4	293.3
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.5	2.0	4.6	7.4	10.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	4.1	13.4	23.0	32.9
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.7	4.1	7.9	20.8	39.5	60.3	83.2
Analysis Tools and Design	0.1	0.1	0.3	0.4	0.7	1.8	10.2	23.7	39.7	55.5
4 Equipment Standards and Analysis	**0.0**	**1.1**	**2.3**	**3.5**	**13.3**	**39.4**	**113.8**	**190.8**	**228.9**	**269.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.4	30.9	45.9	62.3
Standards: EPAct Standards	0.0	1.1	2.3	3.5	10.0	24.6	68.2	111.9	130.2	148.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	3.3	10.1	28.1	48.0	52.8	58.1
Building Technologies Total	**9.3**	**20.5**	**35.5**	**55.1**	**89.2**	**189.5**	**564.6**	**942.6**	**1,208.5**	**1,469.0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.4. Primary Electricity Energy Savings (TBtu/Year)

		2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1	**Residential Buildings Integration**	**0.3**	**0.9**	**1.9**	**3.1**	**4.8**	**9.4**	**28.5**	**57.3**	**98.6**	**151.8**
	Research & Development (Building America)	0.2	0.4	0.9	1.5	2.3	4.0	7.5	9.2	10.1	11.1
	Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.2	2.2	6.0	10.6	15.8
	Zero Energy Buildings	0.2	0.5	1.0	1.6	2.5	5.1	18.8	42.1	77.8	124.9
2	**Commercial Buildings Integration**	**0.0**	**0.3**	**0.6**	**1.0**	**1.8**	**7.6**	**68.5**	**134.7**	**207.8**	**280.4**
	Research & Development	0.0	0.3	0.6	1.0	1.8	6.8	53.9	88.4	117.6	145.8
	Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.9	14.6	46.2	90.3	134.5
3	**Emerging Technologies**	**15.8**	**29.7**	**47.4**	**72.0**	**98.7**	**166.3**	**360.5**	**609.2**	**772.0**	**832.9**
	Lighting R&D: Controls	1.3	2.5	4.0	6.1	8.6	14.7	30.8	39.7	50.3	59.9
	Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	44.6	97.9	161.5
	Refrigeration R&D: Res. HVAC Dist. System	0.7	1.8	3.2	5.2	7.7	15.1	41.7	44.8	25.9	18.2
	Refrigeration R&D: Adv. Elec HPWH	0.0	0.1	0.3	0.7	1.4	3.6	21.5	54.4	68.8	43.8
	Refrigeration R&D: Commercial Refrigeration	0.4	0.9	1.6	2.7	4.1	8.5	27.5	31.9	14.9	2.9
	Refrigeration R&D: Refrigerant Meter	0.0	0.3	0.9	2.0	3.7	9.8	53.4	132.9	162.8	95.8
	Appliances & Emerging Tech R&D: HPWH	2.1	3.4	5.3	8.3	12.2	24.6	55.5	65.2	79.0	94.5
	Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.7	1.2	1.6	1.9	2.3	3.0	3.4	4.0	4.6
	Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Appliances & Emerging Tech R&D: Recessed Can Lights	0.1	0.3	0.8	2.0	3.8	9.7	28.0	33.9	33.9	33.9
	Appliances & Emerging Tech R&D: R-Lamp	2.5	6.6	12.1	19.4	25.2	33.5	3.1	0.0	0.0	0.0
	Window Technologies: Electrochromic Windows	7.0	10.0	13.0	16.6	19.7	26.6	41.5	59.6	81.6	105.8
	Window Technologies: Superwindows	1.7	2.9	4.4	6.4	8.6	14.2	36.8	59.7	88.1	120.5
	Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.9	1.5	2.2
	Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.1	0.7	1.6	2.7	3.9
	Thermal Insulation: Moisture/Wet Insulation	0.0	0.1	0.1	0.1	0.2	0.5	2.3	5.5	9.4	13.8
	Analysis Tools and Design	0.1	0.3	0.6	0.9	1.4	3.1	14.3	31.1	51.4	71.5
4	**Equipment Standards and Analysis**	**0.0**	**3.4**	**6.8**	**10.4**	**35.3**	**83.8**	**213.9**	**339.2**	**382.6**	**427.2**
	Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.2	-0.3
	Standards: EPAct Standards	0.0	3.4	6.8	10.4	25.9	57.3	145.9	228.5	260.8	293.4
	Standards: Distribution Transformers	0.0	0.0	0.0	0.0	9.4	26.5	68.1	110.9	122.0	134.1
	Building Technologies Total	**16.2**	**34.3**	**56.7**	**86.5**	**140.6**	**267.1**	**671.4**	**1,140.4**	**1,461.0**	**1,692.3**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.5. Primary Non-Electric Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.3**	**0.7**	**1.6**	**2.6**	**4.1**	**8.9**	**30.0**	**62.1**	**102.2**	**150.8**
Research & Development (Building America)	0.2	0.5	1.1	1.7	2.7	5.1	9.7	11.8	13.1	14.3
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.7	7.7	20.8	34.6	48.9
Zero Energy Buildings	0.1	0.3	0.5	0.9	1.4	3.2	12.6	29.5	54.5	87.5
2 Commercial Buildings Integration	**0.0**	**0.2**	**0.3**	**0.5**	**1.0**	**4.1**	**34.2**	**50.9**	**58.3**	**65.3**
Research & Development	0.0	0.2	0.3	0.5	1.0	4.1	34.5	52.2	61.0	69.4
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-1.3	-2.7	-4.0
3 Emerging Technologies	**3.9**	**8.5**	**14.5**	**22.7**	**33.8**	**67.6**	**197.5**	**292.0**	**352.2**	**436.3**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.9	2.1	3.9	6.4	10.0	21.1	62.8	68.7	35.8	20.6
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.2	2.6	1.2	0.2
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	-1.0	-1.4	-1.7	-2.0	-2.3	-2.8	-3.4	-3.4	-3.4	-3.3
Window Technologies: Superwindows	3.8	6.6	9.9	14.1	19.2	32.7	85.3	134.4	186.3	241.1
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.4	1.8	4.2	6.7	9.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.3	3.8	12.8	21.9	31.2
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.6	2.7	4.1	7.7	19.8	37.1	56.3	77.2
Analysis Tools and Design	0.0	0.0	0.1	0.1	0.2	0.6	4.3	10.3	17.5	24.5
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**7.6**	**25.4**	**44.0**	**63.2**	**84.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.5	31.0	45.9	62.4
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.9	2.9	7.9	13.0	17.3	21.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**4.2**	**9.4**	**16.5**	**25.9**	**39.9**	**88.3**	**287.1**	**448.9**	**576.0**	**736.5**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.6. Site Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.1**	**0.3**	**0.6**	**1.1**	**1.7**	**3.5**	**11.8**	**24.8**	**42.7**	**65.7**
Research & Development (Building America)	0.0	0.1	0.3	0.5	0.8	1.5	3.1	4.0	4.4	4.8
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	0.9	2.6	4.6	6.9
Zero Energy Buildings	0.1	0.2	0.3	0.5	0.9	2.0	7.8	18.2	33.7	54.1
2 Commercial Buildings Integration	**0.0**	**0.1**	**0.2**	**0.3**	**0.6**	**2.9**	**28.3**	**58.3**	**90.0**	**121.4**
Research & Development	0.0	0.1	0.2	0.3	0.6	2.6	22.3	38.3	50.9	63.1
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.3	6.0	20.0	39.1	58.2
3 Emerging Technologies	**5.0**	**9.6**	**15.9**	**24.3**	**34.6**	**63.0**	**149.0**	**263.7**	**334.2**	**360.5**
Lighting R&D: Controls	0.4	0.8	1.3	2.1	3.0	5.6	12.7	17.2	21.8	25.9
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.3	42.4	69.9
Refrigeration R&D: Res. HVAC Dist. System	0.2	0.6	1.1	1.7	2.7	5.7	17.2	19.4	11.2	7.9
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.1	0.2	0.5	1.4	8.9	23.5	29.8	19.0
Refrigeration R&D: Commercial Refrigeration	0.1	0.3	0.5	0.9	1.4	3.2	11.3	13.8	6.5	1.3
Refrigeration R&D: Refrigerant Meter	0.0	0.1	0.3	0.7	1.3	3.7	22.1	57.5	70.5	41.5
Appliances & Emerging Tech R&D: HPWH	0.7	1.1	1.8	2.8	4.3	9.3	22.9	28.2	34.2	40.9
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.2	0.4	0.5	0.7	0.9	1.2	1.5	1.7	2.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.1	0.3	0.7	1.3	3.7	11.6	14.7	14.7	14.7
Appliances & Emerging Tech R&D: R-Lamp	0.8	2.1	4.1	6.6	8.9	12.7	1.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	2.2	3.2	4.4	5.6	6.9	10.1	17.2	25.8	35.3	45.8
Window Technologies: Superwindows	0.5	1.0	1.5	2.2	3.0	5.4	15.2	25.9	38.1	52.2
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	0.7	1.0
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.7	1.2	1.7
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.0	0.0	0.1	0.2	1.0	2.4	4.1	6.0
Analysis Tools and Design	0.0	0.1	0.2	0.3	0.5	1.2	5.9	13.4	22.3	31.0
4 Equipment Standards and Analysis	**0.0**	**1.1**	**2.3**	**3.5**	**12.4**	**31.7**	**88.4**	**146.9**	**165.6**	**184.9**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1
Standards: EPAct Standards	0.0	1.1	2.3	3.5	9.1	21.7	60.3	98.9	112.9	127.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	3.3	10.1	28.1	48.0	52.8	58.1
Building Technologies Total	**5.2**	**11.1**	**19.1**	**29.2**	**49.3**	**101.2**	**277.4**	**493.7**	**632.5**	**732.6**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.7. Site Natural Gas Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.2**	**0.6**	**1.4**	**2.3**	**3.7**	**7.8**	**25.2**	**51.1**	**83.2**	**122.0**
Research & Development (Building America)	0.1	0.4	1.0	1.6	2.6	4.8	9.2	11.2	12.4	13.6
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.1	0.5	6.2	17.0	28.5	40.6
Zero Energy Buildings	0.1	0.2	0.4	0.7	1.1	2.4	9.8	22.9	42.3	67.9
2 Commercial Buildings Integration	**0.0**	**0.2**	**0.3**	**0.5**	**0.9**	**3.7**	**30.5**	**45.6**	**52.6**	**59.2**
Research & Development	0.0	0.2	0.3	0.5	0.9	3.7	30.7	46.9	55.3	63.2
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-1.3	-2.7	-4.0
3 Emerging Technologies	**2.8**	**6.6**	**11.7**	**18.7**	**28.4**	**58.6**	**174.9**	**259.7**	**312.3**	**388.6**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.8	2.0	3.8	6.2	9.6	20.3	60.4	66.1	34.3	19.7
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.2	2.6	1.2	0.2
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.2	0.6	1.2	2.2	7.0	21.0	25.3	30.1	35.2
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	-1.0	-1.3	-1.6	-2.0	-2.3	-2.7	-3.2	-3.1	-3.0	-2.8
Window Technologies: Superwindows	2.8	4.8	7.2	10.3	14.2	24.5	66.2	107.9	152.8	201.2
Thermal Insulation: Quick Fill Walls	0.0	0.1	0.1	0.1	0.2	0.4	1.7	3.9	6.4	9.1
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.2	3.4	11.6	20.1	28.8
Thermal Insulation: Moisture/Wet Insulation	0.2	0.8	1.5	2.6	4.0	7.6	19.4	36.1	54.6	74.9
Analysis Tools and Design	0.0	0.0	0.1	0.1	0.2	0.6	3.9	9.4	15.9	22.4
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.9**	**7.6**	**25.4**	**44.0**	**63.2**	**84.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	4.7	17.5	31.0	45.9	62.4
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.9	2.9	7.9	13.0	17.3	21.6
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**3.1**	**7.4**	**13.4**	**21.5**	**33.9**	**77.7**	**255.9**	**400.4**	**511.3**	**653.8**

BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.8. Site Fuel Oil Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**1.1**	**4.8**	**11.0**	**19.0**	**28.8**
Research & Development (Building America)	0.0	0.0	0.1	0.1	0.1	0.2	0.5	0.6	0.7	0.7
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	1.5	3.8	6.1	8.4
Zero Energy Buildings	0.0	0.1	0.1	0.2	0.3	0.7	2.8	6.6	12.3	19.7
2 Commercial Buildings Integration	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.5**	**3.7**	**5.3**	**5.8**	**6.1**
Research & Development	0.0	0.0	0.0	0.1	0.1	0.5	3.7	5.3	5.8	6.1
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3 Emerging Technologies	**1.1**	**1.9**	**2.8**	**4.0**	**5.4**	**9.1**	**22.6**	**32.2**	**39.9**	**47.7**
Lighting R&D: Controls	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Res. HVAC Dist. System	0.0	0.1	0.1	0.2	0.4	0.8	2.4	2.6	1.4	0.9
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: HPWH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Appliances & Emerging Tech R&D: R-Lamp	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.2	-0.3	-0.4	-0.5
Window Technologies: Superwindows	1.1	1.8	2.7	3.8	5.0	8.2	19.2	26.6	33.5	39.9
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.4
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.4	1.1	1.8	2.5
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.0	0.0	0.0	0.1	0.4	1.1	1.7	2.4
Analysis Tools and Design	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.9	1.5	2.1
4 Equipment Standards and Analysis	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standards: EPAct Standards	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Building Technologies Total	**1.1**	**2.0**	**3.1**	**4.3**	**6.0**	**10.6**	**31.2**	**48.6**	**64.6**	**82.6**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.9. Carbon Equivalent Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.010**	**0.028**	**0.060**	**0.103**	**0.159**	**0.326**	**1.026**	**2.068**	**3.491**	**5.279**
Research & Development (Building America)	0.005	0.015	0.034	0.057	0.086	0.157	0.291	0.352	0.389	0.425
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.001	0.014	0.164	0.437	0.738	1.057
Zero Energy Buildings	0.005	0.013	0.027	0.046	0.072	0.155	0.571	1.280	2.364	3.796
2 Commercial Buildings Integration	**0.000**	**0.009**	**0.017**	**0.027**	**0.052**	**0.218**	**1.876**	**3.383**	**4.914**	**6.429**
Research & Development	0.000	0.009	0.017	0.027	0.052	0.201	1.588	2.501	3.197	3.869
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.018	0.287	0.882	1.717	2.560
3 Emerging Technologies	**0.348**	**0.690**	**1.142**	**1.808**	**2.524**	**4.432**	**10.137**	**16.229**	**20.307**	**22.744**
Lighting R&D: Controls	0.024	0.047	0.077	0.124	0.175	0.301	0.612	0.773	0.979	1.166
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.867	1.904	3.142
Refrigeration R&D: Res. HVAC Dist. System	0.025	0.064	0.118	0.199	0.303	0.616	1.746	1.875	1.026	0.656
Refrigeration R&D: Adv. Elec HPWH	0.000	0.002	0.006	0.015	0.028	0.073	0.429	1.058	1.338	0.852
Refrigeration R&D: Commercial Refrigeration	0.007	0.017	0.032	0.057	0.088	0.184	0.578	0.659	0.308	0.060
Refrigeration R&D: Refrigerant Meter	0.000	0.005	0.017	0.041	0.076	0.201	1.062	2.586	3.168	1.863
Appliances & Emerging Tech R&D: HPWH	0.038	0.063	0.102	0.168	0.248	0.503	1.104	1.268	1.536	1.838
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.012	0.022	0.032	0.039	0.048	0.060	0.066	0.077	0.089
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.003	0.008	0.017	0.031	0.101	0.302	0.365	0.433	0.507
Appliances & Emerging Tech R&D: Recessed Can Lights	0.001	0.005	0.016	0.040	0.077	0.199	0.555	0.658	0.659	0.659
Appliances & Emerging Tech R&D: R-Lamp	0.045	0.124	0.234	0.393	0.513	0.686	0.063	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.111	0.167	0.228	0.307	0.367	0.504	0.777	1.110	1.537	2.009
Window Technologies: Superwindows	0.091	0.160	0.242	0.352	0.479	0.806	2.063	3.240	4.575	6.031
Thermal Insulation: Quick Fill Walls	0.000	0.001	0.002	0.003	0.004	0.009	0.035	0.079	0.129	0.183
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.005	0.069	0.220	0.377	0.539
Thermal Insulation: Moisture/Wet Insulation	0.003	0.012	0.024	0.041	0.063	0.122	0.335	0.648	1.002	1.393
Analysis Tools and Design	0.002	0.006	0.012	0.021	0.031	0.073	0.349	0.757	1.260	1.757
4 Equipment Standards and Analysis	**0.000**	**0.064**	**0.132**	**0.210**	**0.732**	**1.828**	**4.622**	**7.234**	**8.354**	**9.522**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.068	0.250	0.444	0.658	0.893
Standards: EPAct Standards	0.000	0.064	0.132	0.210	0.541	1.216	3.017	4.632	5.324	6.019
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.191	0.544	1.354	2.158	2.373	2.610
Building Technologies Total	**0.358**	**0.791**	**1.351**	**2.147**	**3.467**	**6.804**	**17.660**	**28.914**	**37.067**	**43.974**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.10. SO_2 Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.011**	**0.021**	**0.036**	**0.055**
Research & Development (Building America)	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.003	0.003	0.003
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.006	0.009
Zero Energy Buildings	0.000	0.000	0.000	0.001	0.001	0.002	0.007	0.015	0.027	0.043
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.003**	**0.021**	**0.038**	**0.058**	**0.077**
Research & Development	0.000	0.000	0.000	0.000	0.001	0.002	0.017	0.026	0.034	0.042
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.012	0.024	0.035
3 Emerging Technologies	**0.004**	**0.008**	**0.014**	**0.024**	**0.033**	**0.057**	**0.114**	**0.177**	**0.224**	**0.244**
Lighting R&D: Controls	0.000	0.001	0.001	0.002	0.003	0.005	0.009	0.010	0.013	0.016
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.012	0.026	0.042
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.001	0.002	0.003	0.005	0.013	0.013	0.008	0.005
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.001	0.006	0.014	0.018	0.011
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.001	0.001	0.003	0.008	0.008	0.004	0.001
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.001	0.001	0.003	0.015	0.035	0.043	0.025
Appliances & Emerging Tech R&D: HPWH	0.000	0.001	0.001	0.003	0.004	0.008	0.016	0.017	0.021	0.025
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.001	0.001	0.003	0.008	0.009	0.009	0.009
Appliances & Emerging Tech R&D: R-Lamp	0.001	0.002	0.003	0.006	0.008	0.011	0.001	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.001	0.002	0.003	0.005	0.006	0.008	0.012	0.015	0.021	0.028
Window Technologies: Superwindows	0.001	0.002	0.003	0.004	0.005	0.009	0.021	0.030	0.041	0.053
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.005
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.009	0.014	0.020
4 **Equipment Standards and Analysis**	**0.000**	**0.001**	**0.002**	**0.003**	**0.011**	**0.026**	**0.061**	**0.089**	**0.100**	**0.112**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.001	0.002	0.003	0.008	0.018	0.041	0.060	0.068	0.077
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.003	0.008	0.019	0.029	0.032	0.035
Building Technologies Total	**0.004**	**0.009**	**0.017**	**0.029**	**0.047**	**0.090**	**0.206**	**0.325**	**0.417**	**0.487**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.11. NO_X Emissions Reductions (MMTons/Year)

		2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1	**Residential Buildings Integration**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.003**	**0.008**	**0.017**	**0.028**	**0.043**
	Research & Development (Building America)	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003
	Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.006	0.008
	Zero Energy Buildings	0.000	0.000	0.000	0.000	0.001	0.001	0.005	0.011	0.020	0.031
2	**Commercial Buildings Integration**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.016**	**0.029**	**0.042**	**0.055**
	Research & Development	0.000	0.000	0.000	0.000	0.000	0.002	0.013	0.021	0.027	0.033
	Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.008	0.015	0.023
3	**Emerging Technologies**	**0.003**	**0.006**	**0.010**	**0.016**	**0.022**	**0.039**	**0.086**	**0.137**	**0.172**	**0.191**
	Lighting R&D: Controls	0.000	0.000	0.001	0.001	0.002	0.003	0.005	0.007	0.009	0.010
	Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008	0.017	0.028
	Refrigeration R&D: Res. HVAC Dist. System	0.000	0.001	0.001	0.002	0.002	0.005	0.014	0.015	0.008	0.005
	Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.001	0.004	0.009	0.012	0.008
	Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.006	0.003	0.001
	Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.001	0.002	0.010	0.023	0.028	0.016
	Appliances & Emerging Tech R&D: HPWH	0.000	0.001	0.001	0.002	0.002	0.005	0.010	0.011	0.014	0.016
	Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
	Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.004
	Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.001	0.002	0.005	0.006	0.006	0.006
	Appliances & Emerging Tech R&D: R-Lamp	0.000	0.001	0.002	0.004	0.005	0.006	0.001	0.000	0.000	0.000
	Window Technologies: Electrochromic Windows	0.001	0.001	0.002	0.003	0.003	0.005	0.007	0.010	0.014	0.018
	Window Technologies: Superwindows	0.001	0.001	0.002	0.003	0.004	0.006	0.016	0.025	0.036	0.048
	Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
	Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.004
	Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.005	0.008	0.011
	Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.006	0.011	0.015
4	**Equipment Standards and Analysis**	**0.000**	**0.001**	**0.001**	**0.002**	**0.007**	**0.016**	**0.041**	**0.063**	**0.073**	**0.083**
	Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.005	0.007
	Standards: EPAct Standards	0.000	0.001	0.001	0.002	0.005	0.011	0.027	0.041	0.047	0.053
	Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.002	0.005	0.012	0.019	0.021	0.023
	Building Technologies Total	**0.003**	**0.007**	**0.011**	**0.019**	**0.030**	**0.060**	**0.151**	**0.246**	**0.315**	**0.372**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.12. CO Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.003**	**0.005**	**0.007**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.005
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.002**	**0.004**	**0.006**	**0.008**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.002	0.003	0.004	0.005
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
3 Emerging Technologies	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.005**	**0.013**	**0.021**	**0.026**	**0.030**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.002	0.001
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.003	0.003	0.002
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.007	0.009
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.005**	**0.008**	**0.010**	**0.011**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.001	0.001	0.003	0.005	0.006	0.007
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003
Building Technologies Total	**0.000**	**0.001**	**0.002**	**0.002**	**0.004**	**0.007**	**0.021**	**0.036**	**0.047**	**0.056**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM

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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.13. PM Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
3 Emerging Technologies	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.005**	**0.005**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.002**	**0.003**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Building Technologies Total	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.004**	**0.007**	**0.009**	**0.011**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.14. VOC Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development (Building America)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Residential Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Zero Energy Buildings	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
2 Commercial Buildings Integration	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**
Research & Development	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001
Commercial Building Energy Codes	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Emerging Technologies	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**
Lighting R&D: Controls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lighting R&D: Next Generation Lighting	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Res. HVAC Dist. System	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Adv. Elec HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Commercial Refrigeration	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Refrigeration R&D: Refrigerant Meter	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: HPWH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Roof Top AC	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Gas Condensing WH	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: Recessed Can Lights	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Appliances & Emerging Tech R&D: R-Lamp	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Electrochromic Windows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Window Technologies: Superwindows	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Thermal Insulation: Quick Fill Walls	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Thermal Insulation: Moisture/Wet Insulation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Analysis Tools and Design	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4 Equipment Standards and Analysis	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**
Standards: Res. Gas Furnaces/Boilers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Standards: EPAct Standards	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Standards: Distribution Transformers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Technologies Total	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.002**	**0.004**	**0.005**	**0.006**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.15. Consumer (Energy) Cost Savings (Million $/Year)

		2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1	**Residential Buildings Integration**	**$4**	**$11**	**$25**	**$41**	**$64**	**$137**	**$459**	**$972**	**$1,655**	**$2,523**
	Research & Development (Building America)	$2	$6	$14	$23	$36	$67	$131	$166	$185	$203
	Residential Building Energy Codes	$0	$0	$0	$0	$1	$6	$72	$199	$340	$491
	Zero Energy Buildings	$2	$5	$11	$18	$28	$64	$256	$607	$1,130	$1,828
2	**Commercial Buildings Integration**	**$0**	**$3**	**$6**	**$9**	**$18**	**$78**	**$724**	**$1,397**	**$2,047**	**$2,708**
	Research & Development	$0	$3	$6	$9	$18	$72	$619	$1,041	$1,346	$1,648
	Commercial Building Energy Codes	$0	$0	$0	$0	$0	$6	$106	$356	$702	$1,061
3	**Emerging Technologies**	**$135**	**$258**	**$431**	**$655**	**$939**	**$1,737**	**$4,340**	**$7,347**	**$9,207**	**$10,290**
	Lighting R&D: Controls	$9	$16	$26	$38	$55	$98	$225	$312	$400	$483
	Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$350	$778	$1,302
	Refrigeration R&D: Res. HVAC Dist. System	$11	$27	$49	$81	$125	$263	$787	$884	$487	$314
	Refrigeration R&D: Adv. Elec HPWH	$0	$1	$2	$5	$10	$29	$193	$514	$654	$419
	Refrigeration R&D: Commercial Refrigeration	$2	$6	$11	$18	$28	$60	$213	$266	$126	$25
	Refrigeration R&D: Refrigerant Meter	$0	$2	$6	$14	$27	$78	$463	$1,218	$1,505	$892
	Appliances & Emerging Tech R&D: HPWH	$15	$24	$39	$62	$93	$203	$505	$626	$763	$919
	Appliances & Emerging Tech R&D: Roof Top AC	$0	$4	$7	$10	$12	$16	$22	$26	$31	$37
	Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$1	$4	$8	$14	$46	$135	$166	$197	$231
	Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$2	$6	$15	$29	$80	$254	$325	$327	$330
	Appliances & Emerging Tech R&D: R-Lamp	$18	$47	$90	$143	$194	$277	$29	$0	$0	$0
	Window Technologies: Electrochromic Windows	$40	$56	$75	$92	$113	$162	$286	$448	$629	$833
	Window Technologies: Superwindows	$38	$66	$100	$143	$197	$339	$910	$1,492	$2,129	$2,833
	Thermal Insulation: Quick Fill Walls	$0	$1	$1	$1	$2	$4	$16	$36	$60	$85
	Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$2	$26	$85	$149	$217
	Thermal Insulation: Moisture/Wet Insulation	$1	$5	$11	$18	$28	$55	$150	$298	$463	$646
	Analysis Tools and Design	$1	$2	$4	$6	$10	$24	$129	$302	$510	$723
4	**Equipment Standards and Analysis**	**$0**	**$22**	**$44**	**$64**	**$230**	**$606**	**$1,722**	**$2,938**	**$3,442**	**$3,981**
	Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$31	$112	$202	$299	$407
	Standards: EPAct Standards	$0	$22	$44	$64	$170	$399	$1,112	$1,866	$2,173	$2,493
	Standards: Distribution Transformers	$0	$0	$0	$0	$60	$177	$498	$870	$969	$1,081
Building Technologies Total		**$139**	**$294**	**$505**	**$769**	**$1,251**	**$2,558**	**$7,245**	**$12,654**	**$16,351**	**$19,502**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.16. Non-Energy Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Research & Development (Building America)	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Residential Building Energy Codes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Zero Energy Buildings	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2 Commercial Buildings Integration	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Research & Development	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3 Emerging Technologies	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Lighting R&D: Controls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Res. HVAC Dist. System	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Adv. Elec HPWH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Commercial Refrigeration	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Refrigeration R&D: Refrigerant Meter	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: HPWH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Roof Top AC	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Appliances & Emerging Tech R&D: R-Lamp	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Window Technologies: Electrochromic Windows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Window Technologies: Superwindows	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: Quick Fill Walls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Thermal Insulation: Moisture/Wet Insulation	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Analysis Tools and Design	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4 Equipment Standards and Analysis	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Standards: EPAct Standards	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Standards: Distribution Transformers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Building Technologies Total	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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BT GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table A-2.17. Incremental Private Investment (Million $/Year)

		2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1	**Residential Buildings Integration**	**$59**	**$95**	**$148**	**$172**	**$225**	**$304**	**$436**	**$576**	**$769**	**$928**
	Research & Development (Building America)	$27	$48	$84	$87	$113	$128	$74	$27	$27	$27
	Residential Building Energy Codes	$0	$0	$0	$0	$3	$18	$100	$136	$145	$155
	Zero Energy Buildings	$31	$47	$64	$84	$110	$158	$262	$414	$597	$746
2	**Commercial Buildings Integration**	**$0**	**$0**	**$0**	**$0**	**$0**	**$22**	**$169**	**$300**	**$354**	**$428**
	Research & Development	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Commercial Building Energy Codes	$0	$0	$0	$0	$0	$22	$169	$300	$354	$428
3	**Emerging Technologies**	**$708**	**$849**	**$1,061**	**$1,303**	**$1,668**	**$2,439**	**$3,790**	**$3,349**	**$3,896**	**$4,041**
	Lighting R&D: Controls	$35	$28	$39	$50	$67	$92	$89	$57	$68	$65
	Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$1	$32	$66	$104
	Refrigeration R&D: Res. HVAC Dist. System	$2	$5	$9	$14	$21	$42	$136	$248	$300	$314
	Refrigeration R&D: Adv. Elec HPWH	$0	$2	$4	$7	$12	$27	$126	$180	$119	$27
	Refrigeration R&D: Commercial Refrigeration	$7	$10	$15	$21	$30	$56	$92	-$22	-$100	$-33
	Refrigeration R&D: Refrigerant Meter	$0	$5	$12	$22	$37	$85	$353	$498	$263	$56
	Appliances & Emerging Tech R&D: HPWH	$34	$22	$34	$50	$68	$135	$89	$92	$95	$98
	Appliances & Emerging Tech R&D: Roof Top AC	$0	$14	$11	$10	$10	$9	$9	$8	$8	$8
	Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$3	$5	$7	$12	$22	-$1	$0	$2	$3
	Appliances & Emerging Tech R&D: Recessed Can Lights	$2	$8	$18	$33	$54	$83	$76	-$43	-$46	$-49
	Appliances & Emerging Tech R&D: R-Lamp	$11	$13	$11	$4	$6	-$26	-$69	-$79	-$81	$-82
	Window Technologies: Electrochromic Windows	$141	$157	$190	$177	$206	$260	$235	$343	$381	$426
	Window Technologies: Superwindows	$463	$557	$678	$857	$1,078	$1,564	$2,480	$1,836	$2,605	$2,865
	Thermal Insulation: Quick Fill Walls	$0	$1	$0	$1	$2	$3	$10	$14	$14	$16
	Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
	Thermal Insulation: Moisture/Wet Insulation	$13	$24	$34	$50	$66	$88	$164	$184	$204	$221
	Analysis Tools and Design	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	**Equipment Standards and Analysis**	**$0**	**$198**	**$205**	**$189**	**$1,568**	**$1,646**	**$2,010**	**$2,213**	**$787**	**$838**
	Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	$25	$8	$6	$3	$0
	Standards: EPAct Standards	$0	$198	$205	$189	$971	$1,036	$1,332	$1,424	$575	$607
	Standards: Distribution Transformers	$0	$0	$0	$0	$597	$584	$669	$783	$210	$231
Building Technologies Total		**$766**	**$1,142**	**$1,414**	**$1,664**	**$3,461**	**$4,411**	**$6,405**	**$6,438**	**$5,806**	**$6,234**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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Table A-2.18. Employment Impacts, Savings Only (Thousand Jobs/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**0.1**	**0.1**	**0.2**	**0.3**	**0.5**	**1.1**	**3.7**	**7.9**	**13.6**	**20.9**
Research & Development (Building America)	0.0	0.1	0.1	0.2	0.3	0.5	1.0	1.3	1.4	1.6
Residential Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.4	2.3	3.4
Zero Energy Buildings	0.0	0.1	0.1	0.2	0.3	0.6	2.2	5.3	9.8	15.9
2 Commercial Buildings Integration	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.5**	**4.9**	**10.3**	**16.3**	**22.5**
Research & Development	0.0	0.0	0.0	0.1	0.1	0.4	3.8	6.6	9.0	11.4
Commercial Building Energy Codes	0.0	0.0	0.0	0.0	0.0	0.1	1.1	3.7	7.3	11.1
3 Emerging Technologies	**1.9**	**2.4**	**3.9**	**6.0**	**8.5**	**15.6**	**37.9**	**65.3**	**82.3**	**90.7**
Lighting R&D: Controls	0.1	0.2	0.3	0.4	0.6	1.0	2.3	3.2	4.1	5.0
Lighting R&D: Next Generation Lighting	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	8.0	13.4
Refrigeration R&D: Res. HVAC Dist. System	0.1	0.2	0.4	0.6	0.9	2.0	5.9	6.7	3.7	2.5
Refrigeration R&D: Adv. Elec HPWH	0.0	0.0	0.0	0.1	0.1	0.3	1.9	4.9	6.2	4.0
Refrigeration R&D: Commercial Refrigeration	0.0	0.1	0.1	0.2	0.3	0.6	2.1	2.7	1.3	0.3
Refrigeration R&D: Refrigerant Meter	0.0	0.0	0.1	0.2	0.3	0.8	4.8	12.5	15.5	9.2
Appliances & Emerging Tech R&D: HPWH	0.2	0.3	0.4	0.6	1.0	2.1	5.2	6.4	7.8	9.4
Appliances & Emerging Tech R&D: Roof Top AC	0.0	0.0	0.1	0.1	0.1	0.2	0.2	0.3	0.3	0.4
Appliances & Emerging Tech R&D: Gas Condensing WH	0.0	0.0	0.0	0.0	0.1	0.2	0.7	0.8	1.0	1.1
Appliances & Emerging Tech R&D: Recessed Can Lights	0.0	0.0	0.1	0.2	0.3	0.8	2.6	3.3	3.4	3.4
Appliances & Emerging Tech R&D: R-Lamp	0.3	0.5	0.9	1.5	2.0	2.9	0.3	0.0	0.0	0.0
Window Technologies: Electrochromic Windows	0.7	0.6	0.8	1.0	1.2	1.8	3.1	4.7	6.6	8.7
Window Technologies: Superwindows	0.4	0.5	0.7	1.0	1.4	2.5	6.6	10.9	15.7	21.0
Thermal Insulation: Quick Fill Walls	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.5
Thermal Insulation: R30 Insulation/30 Year Life Roofs	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.5	0.9	1.3
Thermal Insulation: Moisture/Wet Insulation	0.0	0.0	0.1	0.1	0.2	0.3	0.8	1.7	2.8	3.9
Analysis Tools and Design	0.0	0.0	0.0	0.1	0.1	0.2	1.2	2.8	4.7	6.7
4 Equipment Standards and Analysis	**0.0**	**0.2**	**0.5**	**0.7**	**2.4**	**6.0**	**16.9**	**28.8**	**33.3**	**38.1**
Standards: Res. Gas Furnaces/Boilers	0.0	0.0	0.0	0.0	0.0	0.2	0.5	1.0	1.4	1.9
Standards: EPAct Standards	0.0	0.2	0.5	0.7	1.7	4.0	11.2	18.9	21.9	25.0
Standards: Distribution Transformers	0.0	0.0	0.0	0.0	0.6	1.8	5.1	9.0	10.0	11.2
Building Technologies Total	**2.0**	**2.7**	**4.6**	**7.0**	**11.5**	**23.2**	**63.4**	**112.4**	**145.6**	**172.2**

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Table A-2.19. Income Impacts, Savings Only (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Residential Buildings Integration	**$0**	**$1**	**$1**	**$2**	**$3**	**$7**	**$25**	**$54**	**$95**	**$150**
Research & Development (Building America)	$0	$0	$1	$1	$1	$2	$5	$7	$8	$9
Residential Building Energy Codes	$0	$0	$0	$0	$0	$0	$1	$2	$4	$7
Zero Energy Buildings	$0	$0	$1	$1	$2	$5	$19	$44	$83	$134
2 Commercial Buildings Integration	**$0**	**$0**	**$1**	**$1**	**$2**	**$8**	**$78**	**$172**	**$278**	**$386**
Research & Development	$0	$0	$1	$1	$2	$7	$58	$105	$144	$184
Commercial Building Energy Codes	$0	$0	$0	$0	$0	$1	$20	$68	$134	$202
3 Emerging Technologies	**$21**	**$28**	**$45**	**$67**	**$93**	**$165**	**$384**	**$713**	**$932**	**$1,026**
Lighting R&D: Controls	$2	$3	$5	$7	$10	$18	$42	$58	$75	$90
Lighting R&D: Next Generation Lighting	$0	$0	$0	$0	$0	$0	$0	$65	$145	$243
Refrigeration R&D: Res. HVAC Dist. System	$1	$1	$2	$3	$4	$8	$26	$30	$19	$15
Refrigeration R&D: Adv. Elec HPWH	$0	$0	$0	$1	$1	$3	$23	$60	$76	$48
Refrigeration R&D: Commercial Refrigeration	$1	$1	$2	$3	$5	$11	$38	$47	$22	$4
Refrigeration R&D: Refrigerant Meter	$0	$0	$1	$2	$4	$11	$64	$168	$207	$123
Appliances & Emerging Tech R&D: HPWH	$2	$3	$5	$8	$12	$25	$63	$78	$95	$115
Appliances & Emerging Tech R&D: Roof Top AC	$0	$1	$1	$2	$2	$3	$4	$5	$6	$7
Appliances & Emerging Tech R&D: Gas Condensing WH	$0	$0	$0	$0	-$1	-$3	-$8	-$10	-$11	$-13
Appliances & Emerging Tech R&D: Recessed Can Lights	$0	$0	$1	$2	$4	$10	$32	$41	$41	$41
Appliances & Emerging Tech R&D: R-Lamp	$3	$6	$11	$18	$24	$35	$4	$0	$0	$0
Window Technologies: Electrochromic Windows	$10	$12	$16	$19	$23	$33	$57	$87	$121	$159
Window Technologies: Superwindows	$2	$1	$2	$3	$5	$8	$25	$41	$62	$87
Thermal Insulation: Quick Fill Walls	$0	$0	$0	$0	$0	$0	$0	$0	$0	$-1
Thermal Insulation: R30 Insulation/30 Year Life Roofs	$0	$0	$0	$0	$0	$0	$1	$3	$6	$8
Thermal Insulation: Moisture/Wet Insulation	$0	$0	-$1	-$1	-$1	-$2	-$4	-$7	-$9	$-11
Analysis Tools and Design	$0	$0	$1	$1	$2	$4	$20	$46	$78	$110
4 Equipment Standards and Analysis	**$0**	**$4**	**$8**	**$12**	**$42**	**$103**	**$286**	**$485**	**$551**	**$620**
Standards: Res. Gas Furnaces/Boilers	$0	$0	$0	$0	$0	-$2	-$7	-$12	-$18	$-24
Standards: EPAct Standards	$0	$4	$8	$12	$31	$72	$200	$335	$387	$442
Standards: Distribution Transformers	$0	$0	$0	$0	$11	$33	$93	$162	$181	$202
Building Technologies Total	**$21**	**$33**	**$55**	**$82**	**$140**	**$282**	**$773**	**$1,424**	**$1,855**	**$2,182**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
MDB: K:\METRICS\FY2004\BESET Inputs\Run 5\FY 2004 Run 5.mdb

A.3 Residential Technology R&D

Residential Buildings Integration Decision Unit

Project Objective:[1]

The Residential Technology R&D project consolidates the formerly separate systems engineering projects of Building America, Industrialized Housing, Passive Solar Buildings, and Indoor Air Quality and existing building research into a comprehensive project to accelerate the introduction of highly efficient building technologies and practices through R&D of advanced systems for builders.

Long-Term Goal:[1]

The project's long-term goal is to develop advanced systems to improve the energy performance of over 300,000 homes by 2010. The increased performance will allow the homes to use 50% less energy for space conditioning and water heating than typical homes built in 1993.

Market Segment:

Performance Objective:[2]

- Displaced Technology: Current design/building practices.
- Performance Target: 50% load reduction in space heating and cooling and water heating by 2010.

Target Market[1]

- Market Description: The market includes new single-family, multifamily, and manufactured housing units in all climate zones. The market includes primarily new single-family homes, multifamily infill, HUD code homes, and small commercial buildings. Existing homes would also indirectly benefit from new technologies and improved construction practices developed for new homes.
- Size of Market: Each year ~1.2 million new housing units are built. These units are primarily owner occupied.
- Market Introduction: 1997[2]; this activity was assumed not to occur without DOE funding; therefore, the National Research Council (acceleration-to-market) methodology was not applied.
- Market Penetration Goal:[3] See Table A- 3.1.

Residential Technology R&D

Project Type:
Whole building

Target Market:
New single-family, multifamily, and manufactured housing units with homeowners in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load per household

Modeling Tool:
BESET

Project Manager:
George James/Jon Stone

Website:
http://www.eren.doe.gov/buildings/building_america

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FY 2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.3	0.9	9.1	21.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.005	0.015	0.157	0.352

Consumer Cost Savings (million $):

2004	2005	2010	2020
2	6	67	166

Table A-3.1. FY 2004 Market Penetration for Residential Technology R&D Projects

Year	Annual # Homes
2004	10,800
2005	18,900
2006	33,075
2007	34,729
2008	44,762
2009	47,000
2010	50,916
2011	50,916
2012	45,825
2013	35,132
2014	30,916
2015	29,216
2016	26,795
2017	23,669
2018	19,882
2019	15,508
2020	10,649

Methodology

For any one year, the project's energy savings are calculated by multiplying the number of homes built with Building America techniques that year times the percent savings per home. Added to this are the energy savings, in that year, for Building America homes built in previous years (within the analysis period, any savings resulting from homes built before 2004 are not included).

Project/Technology Consumer Costs:

- **Cost of Conventional Technology** (average price per household)[(4)]:
  - Single Family: $126,700
  - Multifamily: $74,900
  - Manufactured Home: $41,100.
- **Cost of BTS Technology:**[(5)] 2% above conventional cost.
- **Incremental Cost** (average price per household):
  - Single Family: $2,534
  - Multifamily: $1,498
  - Manufactured Home: $822.

Non-Energy Benefits:[(1)]

- Consumer savings of $148 million by 2010
- Improved comfort, durability, and occupant health from better indoor air quality
- Reduced onsite generated waste

- Better sustainability
- Reduced maintenance.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Residential Building Integration R&D Program* (internal BT document).
(2) *FY 2002 GPRA Program Characterization* (internal BT document).
(3) Based on Impacts spreadsheet developed by Ren Anderson, ORNL, August 10, 2000.
(4) Average prices for single-family and multifamily homes are based on information from *MEANS Square Foot Cost 1995* and from Table 3.1b in "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration. eia.doc.gov/emeu/recs/contents.html. Average prices for manufactured housing derived from data provided by the Manufactured Housing Institute, "Manufactured Home Shipments, Estimated Retail Sales and Average Sales Prices" (1997).
(5) *GPRA Metrics for the FY2000 Budget Request: Data Collection Survey*, August, 1998 (internal PNNL document).

A.4 Residential Building Codes

Residential Buildings Integration Decision Unit

Project Objective:[1]

The Residential Building Codes activity, as part of the larger Building Energy Codes project, improves the minimum or baseline energy efficiency of new residential buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for residential buildings. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. Federal, state, and local jurisdictions then adopt and implement these upgraded federal and model energy codes (see the Gateway Deployment decision unit within WIP [Appendix B]).

Long-Term Goal:[2]

The project's long-term goal is to improve the minimum energy efficiency by 20% to 25% in new low-rise residential building construction.

Market Segment:

Target Market[1]

- Market Description: The market includes new residential low-rise buildings three stories or less in height and additions and alterations to existing buildings requiring code permits. (See the Commercial Building Integration decision unit in this appendix for high-rise residential buildings.)

  The project can affect residences major energy end uses, including heating, cooling, water heating, and possibly lighting energy in the near future. All areas of the country are affected because the model building codes and standards cover all climate zones. Household income is not a discrimination of the target market because building codes cover housing at all costs and income levels. Energy-efficiency improvements through codes have repeatedly demonstrated a net positive cash flow to the new home buyer within five years, thereby actually improving household income. The savings from improved appliances and equipment are not included in this project's savings estimates because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Heating and cooling distribution systems are included in this project.

Residential Building Codes

Project Type:
Regulatory

Target Market:
New residential buildings in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% load reduction

Modeling Tool:
Spreadsheet

Project Manager:
Steve Walder

Website:
http://www.energycodes.gov

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FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.8	26.8

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.000	0.014	0.437

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	6	199

Energy savings from this project and from the related Building Energy Codes activities in the Gateway Deployment decision unit result from some basic improvements in overall energy efficiency of commercial buildings. The present funding for conducting research activities for new residential low-rise energy codes is through the Residential Buildings decision unit. Funding for developing core materials (such as compliance tools and training materials) and providing training and financial and technical assistance for states to update and implement their building energy codes is through the Gateway Deployment decision unit. Benefits cannot be clearly allocated to either decision unit.

- Size of Market: Each year ~1.4 million building permits are issued, over a million for single-family dwellings. Although not all jurisdictions currently have energy-efficiency building codes in place, about half of all new residential construction is conservatively estimated to come under building energy code requirements. Also, consumers spend several billion dollars a year remodeling and renovating projects in private residences, about half of which could presently be covered by an energy code. One market not currently covered by codes is manufactured homes, which fall under HUD jurisdiction and regulations.

Methodology

The FY 2004 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 2001 and 2003 editions of the International Energy Conservation Code (IECC) code (to comply with Section 304 of the Energy Conservation and Production Act), and the future development of more stringent building codes. The energy savings methodology was applied at a state level to better link changes in the national codes (e.g., IECC 2003) with variations in climate by states and differences among states in their adoption and enforcement of building codes. The discussion below uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology.

The principal difference between the 1995 Model Energy Code and the IECC 2001 involves the solar heat gain requirements for windows and increased thermal resistance requirements for ducts in unconditioned spaces. Based on a series of simulations for various U.S. locations, the percentage reduction in cooling load was estimated to be ~15%. This requirement increases the heating load by a small amount, ~2% nationally. (The requirement itself is restricted to the southern tier of states). The GPRA estimates were partly based on states' accelerated schedule of adoption of the IECC 2001 and 2003 codes. Through the efforts of the Building Energy Codes project, 31 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

The IECC's ongoing activities were assumed to lead to more stringent residential standards in the future. DOE was assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the IECC standard assumed to become available in the latter part of the current decade. Based on discussions with BT staff, PNNL assumed that the results of these upgrades were to reduce heating and cooling loads in new residential structures by 10%. Without these activities, the analysis assumed that the same standard would be adopted, on average, six years later.

The project's activities also were assumed to improve compliance rates for codes currently adopted by states and localities as well as future building codes. Compliance is increased through better familiarity with the codes over time, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for various standards as discussed above. As a national average, compliance with existing codes was estimated at 45% in 2003, rising to 49% without the project and 72% by 2010 with the project.

The compliance with the several key provisions in the IECC 2000 and 2003 (compared with the 1995 Model Energy Code) was expected to be higher from the outset. On average, the compliance was estimated to be 68% in the year of the adoption. By 2010, compliance rates were assumed to increase to 69% without the project and 74% with the project. For homes that do not comply with the standard, only half of the incremental energy savings were assumed to be achieved by adopting IECC 2001 or 2003.

The analysis assumed that when states first adopt the new standard assumed to become available in the 2006-2007 timeframe, the standard's greater stringency will result in somewhat lower compliance. Initial compliance was assumed to be ~30% at the time of adoption, increasing to 31% without the project and 73% with the project after the first ten years. For IECC 2001 and 2003, the energy savings in units that do not comply were assumed to be 50% of that in units that comply fully with the code.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 5-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $5).

Non-Energy Benefits:[2]

- Lower utility bills
- Improved indoor comfort
- Lower home maintenance and repair activities
- Reduced pollution from with burning fossil fuels and generating electricity, which improves air quality and mitigates the negative impacts of global warming.

Project Strategy (% of budget):[2]

- Research and Development – 0%
- Market Transformation – 0%
- Codes and Standards – 100%.

Sources:

(1) FY 2004 data collection input provided by Jean Boulin, BT/WIP, May, 2002.

(2) FY 2002 Budget – *Data Bucket Report for Residential Buildings Integration R&D Program* (internal BT document).

A.5 Zero Energy Buildings

Residential Buildings Integration Decision Unit

SOLAR BUILDINGS

Project Objective:[1]

U.S. buildings are responsible for 35 quads of energy usage, or 36% of the country's total consumption. This fraction places buildings on a par with industry (also 36%) as a critical element in the effort to improve the country's energy security. A large portion of the energy consumed in buildings is electrical; 67% of every kilowatt-hour sold is for a building application. Electricity demand is divided almost equally between residences (35%) and commercial buildings (32%). Given the enormity of the building sector's energy impact, DOE established the Zero Energy Buildings (ZEB) project to dramatically reduce building energy consumption. The long-term objective of ZEB is to produce a home that uses zero net fossil energy over the course of a year.

Long-Term Goal:[1]

The project's long-term goal is to achieve, through optimal integration of energy efficiency and site generation, sufficient technology advances to enable the following:

- 50% of U.S. housing to be constructed as affordable zero net energy homes by 2010.
- 50% of U.S. commercial buildings to be constructed as, or converted to, affordable zero net energy buildings by 2015.

Market Segment:

Target Market

- Market Description:[2] The market includes new single-family homes. The primary market will be homes constructed in climate zones 4 and 5 (southern U.S.). Further, project construction techniques are likely to be adopted primarily by builders of housing developments where subdivision loads can be aggregated for electric utilities. For analytical purposes, this market consists of the top 200 single-family developers (each of these builders built a minimum of 215 new homes in 2001).
- Size of Market: Each year ~1.2 million new housing units are built. These units are primarily owner occupied. The top 200 builders built over 350,000 of those homes in 2001 (or ~30%).[3]
- Market Introduction: The technology to construct a zero net energy home currently exists; however, penetration into the general market is expected to continue to be extremely low without DOE funding because the technology is currently unaffordable for production home

Zero Energy Buildings Project

Project Type:
Whole building

Target Market:
Residential

End Uses:
All end uses, all fuel types

Unit of Measurement:
% energy consumption reduction

Modeling Tool:
Spreadsheet

Project Manager:
Lew Pratsch

Website:
http://www.eren.doe.gov/solarbuildings

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FY 2004 Benefits

Primary Energy Savings (TBtu)

2004	2005	2010	2020
0.3	0.8	8.3	71.6

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.005	0.013	0.155	1.280

Consumer Cost Savings (million $)

2004	2005	2010	2020
2	5	64	607

builders. Therefore, the National Research Council (acceleration-to-market) methodology was not applied.

- **Market Penetration Goal:**[2,4,5] Of the homes built by the top 200 builders, at least 20% of new high-end homes in the climate zones 4 and 5 would be ZEB by 2010 (a "high-end" home is defined as having an owner with an annual household income >$50,000). This proportion increases to 50% by 2020. Further goals are to build 20% of “middle” homes (owner's annual household income from $25,000 to $50,000) as ZEB by 2020 and to build 20% of low-end homes (owner's annual household income is <$25,000) as ZEB by 2030.

Performance Objective:[2]

- **Displaced Technology:** The project displaces current design/building practices.
- **Performance Target:** The performance target for this project is for houses to have $50/month utility bill by 2004; a $1/day utility bill by 2007; and a 67% load reduction, with remainder of building load to be met by photovoltaics ($0 utility bill), by 2010.

Methodology

For any given year, energy savings for this project are calculated by multiplying the number of homes built with ZEB techniques that year times the percent savings per home. Added to this are the energy savings, in that year, for ZEB homes built in previous years (any savings resulting from homes built before 2004 are not included).

Performance targets were translated into energy consumption reductions by calculating the difference between the average annual energy expenditure per household ($1,295)[6] and the target utility bill, yielding reductions of 54% in 2004, 72% in 2007, and 100% in 2010. Annual delivered energy consumption was assumed to be 100.2 million Btu[7].

The target market was defined as homes built by the top 200 builders, who currently are responsible for building ~30% of all single-family homes each year. Consolidation in the home-building industry was assumed to increase the share of these builders to 40% by 2020 and to 50% by 2030. This market was further refined to reflect the owner's household income level because ZEB homes will initially be targeting the higher-end housing market, followed by middle- and low-end homes. Based on the RECS 1997[8] data for occupied homes constructed in the 1990-1997 period, it was assumed that high-end homes would be represented by those with an annual household income of $50,000 or more (40% of homes); middle-income homes are represented by an annual household income of $25,000 to $49,999 (31% of homes); and low-end homes are represented by an annual household income <$25,000 (29% of homes).[9]

The fundamental premise leading to wide adoption is that existing technologies and projects will eventually reduce energy use by ~67% and reduce summer peak loads to zero. This, in turn, will result significantly in less photovoltaic technology needed to supply the home’s load while shaving summer peak loads and pressure to expand the grid to accommodate peak load growth. With much improved load characteristics, ZEB houses in 2004 to 2007 are expected to receive slightly lower electric rates and by 2010 will have a zero electric bill in return for zero summer peak loads.

Estimates do not include potential applications to manufactured homes or in commercial buildings – both stated project goals. Zero energy homes were assumed to only be likely to penetrate the well-organized, well-trained, subdivision developer market. These developers are assumed to be more likely to negotiate for favorable electrical service with local utilities – based on the ZEB concept. Energy savings resulting from adoption by smaller spec builders and one-off builders are not captured but could be significant if utilities offer a "ZEB" rate to all homeowners.

Project/Technology Consumer Costs:

- Cost of Conventional Technology (average price per household): Single-Family — $210,000. The single-family home price is the 1999 average unit price of homes built by the five largest builders in the U.S.[10]
- Incremental Cost of BTS Technology: Single Family — Initially, modeled as a 5% cost increase over conventional prices (or $10,500)[2] through 2010. Then, because the affordability goal is to have incremental costs no more than five times the average annual energy cost, the incremental cost was modeled to drop to $6,475 in 2015 (five times the average annual energy cost of $1,295).[1]

Non-Energy Benefits:

- Improved comfort in the home resulting from advanced envelope, HVAC designs, and automated energy management systems.[5]

Sources:

(1) Pratsch, L., and J. Talbott. May 1, 2002 (Draft). "Technology Pathways for the DOE Zero Energy Buildings Program," Office of Technology Development Buildings Program, Washington, D.C.
(2) Information obtained in a discussion with the project manager, Lew Pratsch, June 20, 2002.
(3) "The BUILDER 100 Database" and "The Next 100" at www.builderonline.com.
(4) Information obtained in a discussion with the project manager, Lew Pratsch, July 11, 2002.
(5) Information obtained in a discussion with the project manager, Lew Pratsch, July 17, 2002.
(6) BTS Core Databook (July 13, 2002), Table 4.2.5, "Average annual energy expenditure for homes constructed in 1996-1997."
(7) BTS Core Databook (July 13, 2002), Table 1.2.6, "Average delivered energy consumption for homes constructed in 1996-1997."
(8) "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration, Washington, D.C. eia.doc.gov/emeu/recs/contents.html
(9) Table HC1-3a, "Housing Unit Characteristics by Household Income, Million U.S. Households, 1997," in "Residential Energy Consumption Survey." 1997. U.S. Department of Energy, Energy Information Administration, Washington, D.C. eia.doc.gov/emeu/recs/contents.html
(10) BTS Core Databook (July 13, 2002), Table 5.1.1, "2001 Five Largest Residential Homebuilders."

A.6 Commercial Buildings Technology R&D

Commercial Buildings Decision Unit

Project Objective:

The Commercial Buildings Technology R&D project develops and demonstrates advanced technologies, controls, and equipment in collaboration with the design and construction community. The project focuses on advancing integrated technologies and practices to optimize whole-building energy performance. The project reduces energy use in commercial and multifamily buildings by promoting practices that help ensure the industry constructs buildings as designed and operates them at or near the optimum level of performance.

Long-Term Goal:

The project's long-term goal is to improve the energy efficiency of the nation's new commercial buildings by 30% and existing buildings by 20% compared with buildings built in 1996.

Market Segment:

Performance Objective(1)

- Displaced Technology: The project displaces conventional design/ building practices.
- Performance Target:
  - By 2004 reduce heating and cooling loads by 30% in new construction and by 20% in existing units
  - By 2010 reduce heating and cooling loads by 50% in new construction and by 30% in existing units.
  - By 2020 reduce heating and cooling loads by 60% in new construction and 40% in existing units.

Target Market(1)

- Market Description: Although this project does not explicitly exclude any particular building type, the types of commercial buildings that will most likely be impacted by the technologies developed by this project include buildings with relatively higher energy use intensities such as assembly, education, food service, food sales, health care, lodging, mercantile and service, and office buildings.
- Market Introduction: 1996 (inception date of project is 1977). Products supported by this project were assumed not to be developed without DOE funding; therefore, the National Research Council (acceleration-to-market) methodology was not applied.

Commercial Buildings Technology R&D

Project Type:
Whole building

Target Market:
New and existing commercial and residential multifamily units in all climate zones

End Uses:
Heating and cooling

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Dru Crawley

Website:
http://www.eren.doe.gov/buildings/highperformance

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.5	10.9	140.6

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.009	0.201	2.501

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	3	72	1041

- **Market Penetration Goal:** The market penetration goal is to penetrate 60% of new commercial and multifamily construction by 2020 in combination with the Analysis Tools and Design Strategies project and to penetrate 20% of the existing commercial and multifamily buildings by 2020 (see Figure A-6.1).

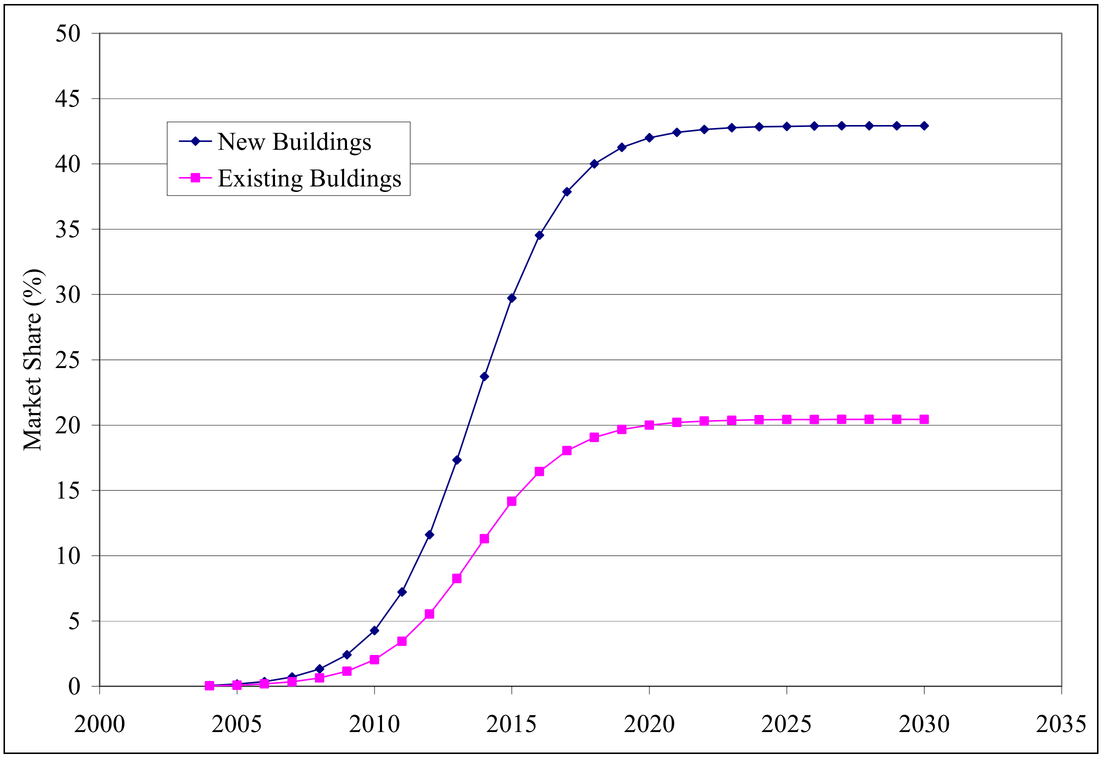

Figure A-6.1. Market Penetration Curve for Commercial Technology R&D Projects

Non-Energy Benefits:

- Reduced operation and maintenance expenses
- Improved indoor environmental quality
- Increased property asset value
- Higher tenant satisfaction and retention rates
- Increased technology sales.

Sources:

(1) Interview with the project manager, Dru Crawley, August, 2001.

A.7 Commercial Building Codes

Commercial Buildings Integration Decision Unit

Project Objective:[1]

The Commercial Building Codes activity, as part of the larger Building Energy Codes project, improves the minimum energy efficiency of new commercial and multifamily high-rise buildings and additions and alterations to existing buildings requiring code permits. The project promulgates upgraded energy-efficiency requirements for federal commercial and high-rise residential building types. Similarly, the project works with model energy code groups to upgrade the energy-efficiency requirements of their codes. These upgraded federal and Model Energy Codes are then adopted and implemented by federal, state, and local jurisdictions (see the Gateway Deployment decision unit within WIP [see Appendix B]).

Long-Term Goal:[1]

The project's long-term goal is to improve minimum energy efficiency by 30% to 35% in new commercial building construction. Energy use will be reduced by states and local jurisdictions widely adopting building energy codes.

Market Segment:

Target Market

- Market Description: The market includes all new commercial and multifamily high-rise buildings and all additions and renovations to buildings requiring code permits.
- Size of Market: The market size is ~2 billion ft^2 of new commercial floor space. The federal sector represents ~2.3% overall of new commercial building construction.

Methodology

Energy savings from this project and from the related building energy code activities in the Gateway Deployment decision unit (WIP) result from some basic improvements in the overall energy efficiency of commercial buildings. The present funding for conducting research activities for new commercial and multifamily high-rise energy codes is through the Commercial Buildings Integration decision unit.
Funding for developing core materials (such as compliance tools and training materials) and providing training and financial and technical assistance for states to update and implement

Commercial Building Codes

Project Type:
Regulatory

Target Market:
New commercial buildings and additions and alterations to existing buildings in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
Spreadsheet

Project Manager:
Ron Majette

Website:
http://www.energycodes.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.9	45.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.000	0.014	0.437

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	6	356

their building energy codes is through the Gateway Deployment decision unit. Benefits cannot be clearly allocated to either decision unit, thus the benefits estimated here are a function of both training and deployment as well as development of the commercial building energy codes and standards.

Barring future guidance from DOE, benefits for FY 2004 were assumed to be allocated according to the ratio of actual funding levels. The description of the methodology below also pertains to Training and Assistance for Codes project in Appendix B.

The project's impact is primarily through two avenues: 1) developing and supporting code changes to improve the minimum energy-efficiency requirements for commercial and multifamily high-rise buildings and 2) providing technical and financial assistance to states to update and implement their building energy codes. The latter includes developing tools that can ease the adoption of new codes and through their use, can support improvements in compliance and enforcement of code provisions. Tools take the form of code compliance software, computer-based training tools for building energy codes, and tools for implementing noncomputer-based codes.

Improvements to building codes are primarily supported by research efforts to review existing codes and specific targeted areas of building energy use and the adoption of code modifications that promote cost-effective reductions in these energy-use areas. Support for the research work has typically taken place in three areas:

- Upgrading ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings"(2)
- Ugrading the federal commercial and multifamily high rise building energy code, 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings"(3)
- Upgrading the International Energy Conservation Code (IECC).(4)

The FY 2004 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2002 editions of ASHRAE 90.1-1999(5) standard (to comply with Section 304 of the Energy Conservation and Production Act), and the future development of more stringent building energy codes. The energy savings methodology was applied at a state level to better link changes in the codes (e.g., IECC 2003) with variations in climates by states and differences among states in their adoption and enforcement of building codes. The discussion below uses national averages of some of the key assumptions related to adoption and compliance to help summarize the methodology, but appropriate state averages were used in the analysis.

The principal differences between the ASHRAE 90.1-1989, 90.1-1999, and 90.1-2002(6) standards relate to requirements for better windows, reduced installed wattage for lighting, and more efficient heating and cooling equipment. The savings from improved equipment are not included in the project's savings estimates because they are reflected in the Equipment Standards and Analysis decision unit in this appendix. Based on a series of simulations that include various U.S. locations and that were developed specifically to evaluate the two

ASHRAE standards (often referred to as the “determination” study[7]), the average reduction in site energy use was estimated to be ~3.5% or ~2 MMBtu/sq ft. The GPRA estimates were partly based on states' accelerated adoption schedule of the ASHRAE 90.1-1999 and 90.1-2002 standards. Through the efforts of the Building Energy Codes project, 35 states were assumed to have adopted the standard by the end of 2005. The project was assumed to accelerate the adoption of the standard by an average of four years nationwide.

The ongoing activities of the ASHRAE 90.1 committee were assumed to lead to more stringent commercial building standards in the future. DOE was assumed to play a major role in developing the analytical and economic basis for such standards. For the GPRA process, these activities were subsumed in a single upgrade of the ASHRAE standard assumed to become available in the latter part of the current decade. The GPRA analysis assumed that the overall result of these upgrades is to reduce electricity consumption by 10% and natural gas consumption by 2% in new commercial buildings. Many states adopting this standard by 2010 also depends on the project's continuing activities to assist states in the adoption (and compliance) process. Without these activities, the analysis assumed that the same standard would be adopted, on average, six years later.

The project activities were also assumed to improve compliance rates for codes currently adopted by states and localities as well as future building codes. Compliance is increased through increased familiarity with the codes over time, simplifications to the code while maintaining stringency, and the availability and increased use of compliance tools by builders and enforcement officials. Compliance rates, with and without the project, were estimated for the existing code, a code based on ASHRAE 90.1-1999, and a future standard as discussed above. On a national average basis, compliance with existing codes was estimated at 60% in 2000, rising to 66% without the project, and 79% by 2010 with the project.

The compliance with the several key provisions in ASHRAE 90.1-2001 (compared with 90.1-1999) was expected to be higher from the outset. On average, PNNL estimated the compliance to be 65% in the year of the adoption. Ten years later, compliance rates were assumed to increase to 67% without the project and 72% with the project. For buildings that do not comply with the standard, only half of the incremental energy savings were assumed to be achieved by adopting the ASHRAE 90.1-2001 standard.

The analysis assumed that the simplifications in the ASHRAE 90.1-1999 and 90.1-2001 standards will be extended to the new standard and will result in somewhat higher compliance when states first adopt them. Initial compliance was assumed to be ~27% at the time of adoption, rising to 31% without the project and 73% with the project after the first ten years. The energy savings in buildings that do not comply with the new standards were assumed to be 65% of that in buildings that comply fully with the code.

Project/Technology Consumer Costs (PNNL Estimates):

- Incremental investment costs were developed assuming a 5-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $5).

Non-Energy Benefits:

- Improved environment and more comfortable buildings.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Commercial Buildings Codes Program* (internal BT document).
(2) ASHRAE/IES Standard 90.1-1989, "Energy Efficient Design of New Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers and Illuminating Engineering Society.
(3) 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings," *Code of Federal Regulations*, as amended.
(4) International Energy Conservation Code. 2003. International Code Council, Falls Church, Virginia.
(5) ASHRAE/IES Standard 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(6) ASHRAE/IES Standard 90.1-2002, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(7) U.S. Department of Energy. March 2002. "Commercial Buildings Determinations, Explanation of the Analysis and Spreadsheet (90_1savingsanalysis.xls)." http://www.energycodes.gov/implement/determinations_com.stm

A.8 Lighting R&D

Emerging Technologies Decision Unit

Project Objective:[1]

The Lighting R&D project develops and accelerates the introduction of advanced lighting technologies.

Long-Term Goal:[1]

The project's long-term goal is to reduce lighting energy use by 50% by 2020.

Market Segment

Target Market

- Market Description: The market includes all commercial buildings, with some technologies being introduced into residential buildings.
- Size of Market: Lighting consumes 26% (3.9 quad) of the primary energy used in commercial buildings, which had a building stock of ~69 billion sq ft in 2000[2].

Methodology

The energy savings from the lighting project are generally based on the judgment of the BT project managers and PNNL analysts as to the probable penetration of specific lighting technologies. Beginning with the FY 2003 GPRA process, an effort was made to estimate energy savings from BT activities designed to increase the adoption and effectiveness of lighting controls. PNNL continues to use a spreadsheet to develop the energy savings estimates for this project.

Various field studies[3] have shown a very large energy savings potential for lighting controls, primarily using occupancy and daylighting controls. These studies have shown that aggressively implementing controls can save 20% to 40% of lighting energy use. BT supports the development of more advanced systems—through both research and field testing—that will further reduce energy used for lighting in commercial buildings. BT support of research to evaluate the interrelationship between human vision and efficient light use will also contribute to future energy savings.

Lighting R&D

Project Type:
Equipment efficiency

Target Market:
Potentially all sectors and all climate zones (primarily impacts commercial sectors and higher-income residential)

End Uses:
Lighting and electricity

Unit of Measurement:
Lumens/watt

Modeling Tool:
Spreadsheet

Project Manager:
Ron Lewis

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
1.3	2.5	14.7	39.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.024	0.047	0.301	0.773

Consumer Cost Savings (million $):

2004	2005	2010	2020
9	16	98	312

For FY 2004, the impact of the BT activities in lighting controls and efficient lighting practices was assumed to yield an incremental 5% reduction in lighting energy use compared with current practice. (By *incremental*, the BT activities are assumed to lead to further savings over and above the control technologies that the private sector offers now and are likely to offer.)

This assumption represents a technical potential—PNNL further assumed that up to 80% of new commercial buildings could incorporate these technologies and that 20% of the existing stock could be retrofitted with these systems. A time profile of penetration rates was based on the historical pattern of market penetration observed for electronic ballasts. An S-shaped penetration curve was fit to historical market shares for electronic ballasts and then applied to project future adoption of advanced lighting distribution systems and controls. (This curve indicated that ~50% of the ultimate market penetration was achieved after 9 years).

PNNL developed a simple spreadsheet model to generate the energy savings estimates based on these assumptions. NEMS-PNNL was not used because it primarily competes different types of lighting sources—the BT activities in this area are designed to reduce the demand for all lighting sources. Implicitly, NEMS-PNNL requires input assumptions regarding lighting demand (lumen/sq ft), but these values are fixed over the forecast horizon. BESET also cannot modify lighting demands over time.

The spreadsheet model required several key baseline inputs. Projected annual floor space additions by building type were based on *Annual Energy Outlook 2001*(4) and were taken from the BESET database. PNNL took the baseline energy use per square foot for lighting by building type from PNNL's 1997 study to estimate end-use energy consumption for U.S. commercial buildings.(5) We applied the model to the following building types: offices, retail, education, health services, assembly, and lodging.

The spreadsheet approach embodies a somewhat different methodology compared with BESET to determine the savings in existing buildings. Existing buildings in the spreadsheet model are all buildings that did *not* adopt the BT-sponsored technologies during construction and thus include the current (2003) stock of buildings as well as those that will be built during the forecast period but that do not initially install these technologies.

In BESET, existing buildings primarily refer only to buildings built before the base year of the forecast horizon (e.g., pre-2004 buildings). The approach in this analysis reflects the assumption that future renovations of both existing and post-2003 buildings will provide opportunities to economically install these technologies.

These assumptions lead to an estimate of ~18.5 billion square feet of commercial buildings adopting these technologies by 2020, with a little more than half of the adoptions occurring after the buildings were first constructed (i.e., existing buildings). This amount of floor space represents ~31% of the total floor space in the building types considered.

Project/Technology Consumer Costs (PNNL Estimates):

- Incremental investment costs were developed assuming a 4-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $4).

A.8 Lighting R&D

Emerging Technologies Decision Unit

Non-Energy Benefits:

- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate change goals
- Improves U.S. productivity from better lighting in work environments
- Responds to an industry-initiated collaborative.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Lighting R&D Program* (internal BTS document).
(2) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C.
(3) See http://eande.lbl.gov/btp/450gg/publications.html and www.cmpco.com/services/pubs/lightingfacts/controls.html
(4) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.
(5) Belzer, D.B., and L.E. Wrench. 1997. *End-Use Energy Consumption Estimates for U.S. Commercial Buildings, 1992*. PNNL-11514, Pacific Northwest National Laboratory, Richland, Washington.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Project Objective:(1)

The Next Generation Lighting Initiative develops and accelerates the introduction of solid-state lighting and seeks to achieve the following for lighting:

- Significantly greater efficacy than conventional sources, such as T8 fluorescents
- Easy integration into building systems of the future
- Ability to provide the appropriate color and intensity for any application
- Ability to last 20,000 to 100,000 hours
- Ability to readily supplement natural sunlight.

Long-Term Goal:(1)

The project's long-term goal is to reduce lighting energy use by 50% by 2020.

Market Segment

Target Market

- Market Description: The market includes all commercial buildings, with some technologies being introduced into residential buildings.
- Size of Market(4): Lighting consumes 26% (3.9 QBtu) of the primary energy used in commercial buildings, which had building stock of ~69 billion ft^2 in 2000.[b]

Methodology

The energy savings from the lighting project are generally based on the judgment of the BT project managers and PNNL analysts as to the probable penetration of specific lighting technologies. Formally, however, NEMS-PNNL was used to develop the savings calculations. The capital costs of the technologies are adjusted to achieve approximate congruence with the external penetration assumptions. The FY 2004 GPRA process focuses on solid-state lighting, which is expected to have a substantial increase in funding.

Lighting R&D: Next Generation Lighting

Project Type:
Equipment efficiency

Target Market:
Potentially all sectors and all climate zones (primarily impacts commercial sectors and higher-income residential)

End Uses:
Lighting and electricity

Unit of Measurement:
Lumens/watt

Modeling Tool:
NEMS-PNNL

Project Manager:
Ron Lewis

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FY 2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.0	0.0	0.0	44.6

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.00	0.00	0.00	0.867

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	0	0	350

[b] According to a recent report completed for DOE by Navigant Consulting ("U.S. Lighting Market Characterization, Volume I: National Lighting Inventory and Energy Consumption Estimate," September 2002), the amount of energy used for lighting is greater than EIA has traditionally estimated. The report estimates that commercial lighting requires 4.2 QBtu and residential lighting requires 2.2 QBtu. This report, however, was distributed after the FY04 GPRA estimates were prepared, so PNNL's estimates are based on EIA's estimates.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Key assumptions concerning the likely dates of introduction and the expected efficacies were influenced by two sources: 1) "The Case for a National Research Program on Semiconductor Lighting,"(2) a white paper prepared by Hewlett-Packard and Sandia National Laboratories and presented in late 1999 at an industry forum; and 2) a more extended study(3) by A.D. Little for BT in early 2001; the study used some of the basic assumptions in the white paper(2) in developing some scenarios related to solid-state lighting.

The most recent work pertaining to the goals of the Next Generation Lighting Initiative, however, is a series of cost and performance projections prepared by Lincoln Technical Services (LTS) in the fall of 2002.[c] For the FY04 GPRA effort, the LTS estimates were used exclusively to drive the input assumptions used in the NEMS-PNNL model.

The LTS estimates were predicated on a substantial rampup of funding for this area of research by DOE. Within about five years, the funding for this activity was expected to increase to about $50 million per year, remaining at that level for a decade or longer. A set of energy savings estimates was developed in October of 2002 that reflected this scenario.

In late January of 2003, PNNL was asked to prepare a revised set of estimates based on a substantial scaling back of the proposed increase in this research area, corresponding to the final BT budget request. The revised budget case calls for some increase in funding, and then leveling out at about $5 million per year. The DOE program manager, Jim Brodrick, suggested that this reduction would likely stretch out the project goals for a viable commercial product by seven years or longer. Moreover, the rate of improvement and cost reduction, envisioned in the LTS projections, would also be reduced. These assumptions were used to modify the LTS projections as inputs to the NEMS-PNNL model.

As with the previous work for the FY 2002 and FY 2003 GPRA process, we used the NEMS-PNNL model to project energy savings from the initiative. The current model competes a wide variety of technologies and incorporates the EIA's functions that were used to represent declining costs of new technologies.

For the FY 2004 GPRA estimate, the savings estimates are based on NEMS-PNNL projections modeling the solid-state lighting technologies supported under the Next Generation Lighting Initiative. In either budget scenario, this initiative will increase the research funding for the solid-state lighting sources. The approach suggested by the National Research Council is that the commercial introduction of these technologies might be advanced by ten years as a result of DOE's role. However, in the case described here, the energy savings path essentially assumes that the technology would not be introduced without DOE support. In part, this assumption stems from the time horizon of the *Annual Energy Outlook 2002* version of NEMS-PNNL that does not extend beyond 2020.

NEMS-PNNL characterizes each lighting technology by source efficacy level (lumens/watt), capital cost ($/1000 lumens or $/kLumen), and annual maintenance cost of lamps. For new

[c] Spreadsheet named Dave.data1.xls transmitted by Michael Scholand of Navigant Consulting, Inc. on October 30, 2002.

technologies, the capital costs can be reduced along a logistic-shaped curve. The NEMS-PNNL model divides the commercial lighting market into four major groups: 1) incandescent CFL (point source), 2) 4-foot fluorescent, 3) 8-foot fluorescent, and 4) high-intensity point source (outdoor lighting). Solid-state lighting was assumed to penetrate the first three market groupings.

Given the cost assumptions, the NEMS-PNNL model chooses among these technologies for each building type in each census division. For each group, the market is assumed to be further segmented, with each segment characterized by a different discount rate in its decision-making criteria. Within each segment, a lighting technology is selected based on minimum annualized cost.

Table A-9.1 summarizes the cost inputs for some of the key lighting technologies used in NEMS-PNNL for FY 2004. The first round of FY 2004 estimates (consistent with the substantially higher budget levels) was based upon the efficacy of solid-state lighting reaching 160 lumens/watt in 2010, 180 lumens/watt by 2015, and 208 lumens/ watt by 2018. In the revised budget case, as the table shows, the 160 lumen/watt performance goal was delayed until 2017. Some improvement in the performance and a decrease in cost was assumed for the 2019 input.

Non-Energy Benefits:

- Helps maintain U.S. semi-conductor leadership
- Develops U.S. leadership in lighting technology
- Reduces pollution and contributes to U.S. climate change goals
- Improves U.S. productivity from better lighting in work environments
- Responds to industry-initiated collaborative.

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Table A-9.1. Solid-State Lighting Cost and Efficiency Assumptions—FY 2004 GPRA

	Efficacy (Lumen/ watt)	Light Source Cost ($/kLumen) (2010)	Light Source Cost ($/kLumen) (2017)	Light Source Cost ($/kLumen) (2019)	Light Source Cost ($/kLumen) (2020)	Annual Oper. Cost ($/yr)
Incandescent / CFL						
Incandescent A19	15	0.25	0.25	0.25	0.25	6.50
CFL (pin-base, 20 watts)	60	4.89	4.70	4.52	4.34	1.75
CFL (integral, 20 watts)	60	8.00	7.69	7.39	7.10	1.75
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	0.87
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
4-foot Fluorescent						
Halogen reflector lamp	14	5.84	5.84	5.84	5.84	15.77
F32T8 Electronic	80	1.01	0.97	0.93	0.90	2.80
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	2.53
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
8-foot Fluorescent						
F96T12 - Electronic ES	61	3.01	2.89	2.77	2.66	5.25
F96T12 - Electronic HO	52	1.88	1.81	1.74	1.67	9.64
Solid state (2017 intro)	160	NA	12.00	12.00	12.00	2.50
Solid state (2019 intro)	164	NA	NA	11.20	11.20	0.87
NA = Not applicable.						

A.9 Lighting R&D: Next Generation Lighting

Emerging Technologies Decision Unit

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Lighting R&D Program* (internal BT document).
(2) Haitz, R., and F. Kish (Hewlitt-Packard Co) and J. Tsao and J. Nelson (Sandia National Laboratories). 1997. "Case for a National Research Program on Semiconductor Lighting," White paper presented at the 1999 Optoelectronics Industry Development Association forum in Washington D.C., October 6, 1999.
(3) A.D. Little. 2001. *Energy Savings Potential of Solid State Lighting in General Lighting Applications*. Prepared for DOE's Office of Building Technology, State and Community Programs by A.D. Little, Cambridge, Massachusetts.
(4) *Annual Energy Outlook 2002*. 2002. Energy Information Administration, Washington, D.C.

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project Objective:[1]

This project develops and promotes the use of commercial food display and storage technologies that use less energy and less refrigerant. Water-heating activities are centered on developing low-cost, high-reliability heat pump water heater concepts. The project's HVAC delivery (e.g., duct work) technologies are intended to reduce the energy losses incurred in transferring heating or cooling from the conditioning unit(s) (e.g., heat pump, furnace, and air conditioner) to the conditioned space. The refrigerant pressure charge meter and coefficient of performance (COP) meter enables early warning of poor operation of HVAC equipment to keep installed equipment operating at design efficiencies during the service life.

Long-Term Goal:[1]

The long-term goal of this project includes reducing energy use for building space heating and cooling by 20% to 25% (22.5% assumed) and supermarket refrigeration and energy use by 10% to 20% (15% assumed) while reducing the level of refrigerant needed.

Market Segment:

Target Market

- Market Description:[1] The market includes commercial refrigeration, a broad classification of building equipment that collectively consumes about one quad of U.S. energy annually[2]. Supermarkets consume about one-third of the energy used in commercial refrigeration. Residential applications include air conditioners, heat pumps, heat pump water heaters, and thermal distribution systems associated with forced air systems.
- Size of Market:[1] Commercial refrigeration markets include ~30,000 large supermarkets and 100,000 convenience stores. Other markets include hospitals, large institutional buildings, and restaurants. Residential markets include new, single-family, and existing homes.

Methodology

For FY 2004, four technologies were modeled: commercial refrigeration, residential HVAC distribution

Space Conditioning and Refrigeration R&D

Project Type: Equipment efficiency

Target Market: Refrigeration: commercial food sales in all climate zones; Heat Pump Water Heater and HVAC Distribution: residential; Refrigerant Pressure Charge Meter and COP Meter: residential and commercial

End Uses: Heating, cooling, and water heating

Unit of Measurement: Refrigeration: % end-use consumption; Heat Pump Water Heater and Refrigerant Meter: efficiency/unit; HVAC Distribution: % change in load

Modeling Tool: Refrigeration: spreadsheet; HVAC Distribution, Heat Pump, Water Heater, and Refrigerant Meter: BESET

Project Manager: Arun Vohra

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FY 2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
2.0	5.2	58.7	335.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.032	0.088	1.074	6.178

Consumer Cost Savings (million $):

2004	2005	2010	2020
13	36	430	2882

systems (existing and new construction), advanced electric heat pump water heaters, and refrigerant pressure charge meters and COP meters.

Commercial Refrigeration

This project was modeled as an advanced supermarket refrigeration system that would target heating, cooling, and refrigeration end-use loads in the commercial food sales sector. These end uses comprise ~66% of total building, ~67% of electric, and 61% of total natural gas end-use energy consumption.(3)

To calculate the project's energy savings, the overall reduction in end-use energy consumption was applied to the estimated consumption per square foot within food sales buildings. This per-square-foot energy-savings level was aggregated to a project total based on a forecast of square feet of food sales buildings and an estimated market penetration curve.

Performance Objective:

- **Displaced Technology:** Conventional refrigeration equipment in food sales buildings.
- **Performance Target:** Reduced energy for building HVAC and refrigeration equipment over the next 15 to 20 years, specifically at least 15% for supermarket refrigeration and HVAC while reducing refrigerant needed. For FY 2004, PNNL assumed an overall 22.5% reduction in HVAC end-use energy consumption.

Market Penetration:

- **Target Market:** All commercial food sales buildings.
- **Market Introduction:** 2004; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal for New Buildings:** 93% penetration of all commercial food sales buildings by 2020 and 99% by 2030 (see Figure A-10.1).

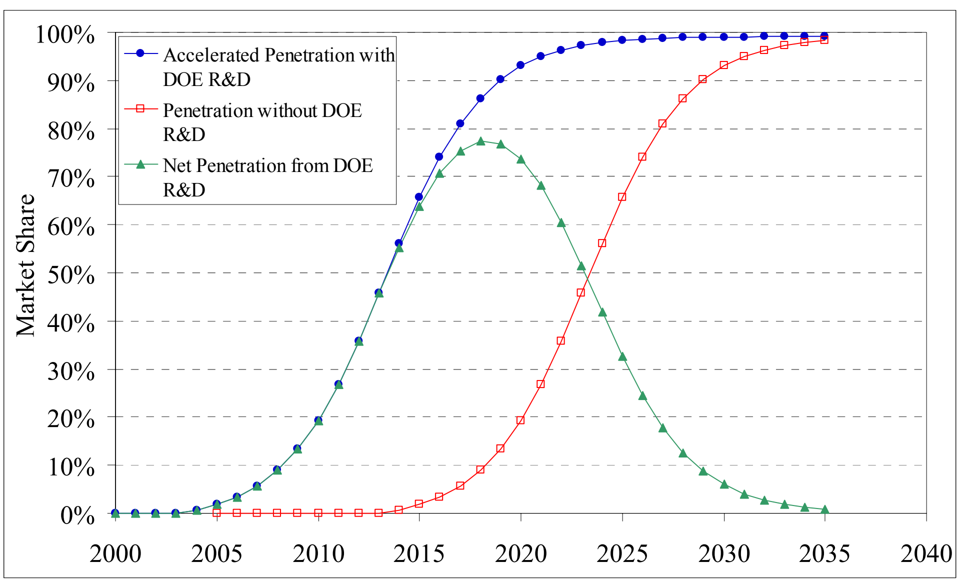

Figure A-10.1. Market Penetration Curve for Commercial Refrigeration

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

Residential HVAC Distribution Systems – Existing Construction

This technology, aeroseal sealing, and other projects designed to reduce duct leakage in existing residences will reduce the energy liabilities of residential ductwork. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in heating, cooling, and ventilation to the estimated consumption per square foot within existing single-family buildings. Ventilation consumption and savings were assumed to be included in the heating and cooling consumption and savings. The per-square-foot energy-savings level was then aggregated to a project total based on a forecast of single-family building square feet and an estimated market penetration curve.

Performance Objective for Existing Construction:

- Displaced Technology: Current duct work, with the performance described in Table A-10.1.
- Performance Target: Table A-10.1 shows the reductions in HVAC end-use energy consumption that were assumed for FY 2004.

Table A-10.1. Assumed Reductions in Energy Use for Residential HVAC Distribution Systems (existing construction)

End Use	Percentage Reduction in Energy Consumption
Heating	13.8*
Cooling	6.9**

* Conductive and air leakage losses have about equal contribution to duct system energy loss.[4] The energy savings associated with duct sealing is assumed to be roughly equivalent to the savings possible through better design. The seasonal heating distribution (which includes conduction through duct walls and air leakage through duct system holes and joints for ducts located in unconditioned spaces) efficiency of typical current ducts is ~56% and ~72% for good conventionally designed ducts with R-4 duct insulation.[5] Single-family buildings with ducts can reduce heating energy consumption by 22.2% (1 – 56%/72%). With ~50% of existing single-family homes using ducts,[4] the overall per building heating savings are 11.1% (22.2% * 50%).

** The seasonal cooling efficiency of typical current ducts is ~75% and ~87% for good conventionally designed ducts with R-4 duct insulation.[5] Single-family buildings with ducts can reduce cooling energy consumption by 13.8% (1 – 75%/87%). With ~50% of existing single-family homes using ducts,[6] the overall per building cooling savings are 6.9% (13.8% * 50%).

Market Penetration for Existing Construction:

- **Market Introduction**: 2004; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years
- **Market Penetration Goal**: 20% of existing single-family units by 2020 (see Figure A-10.2).

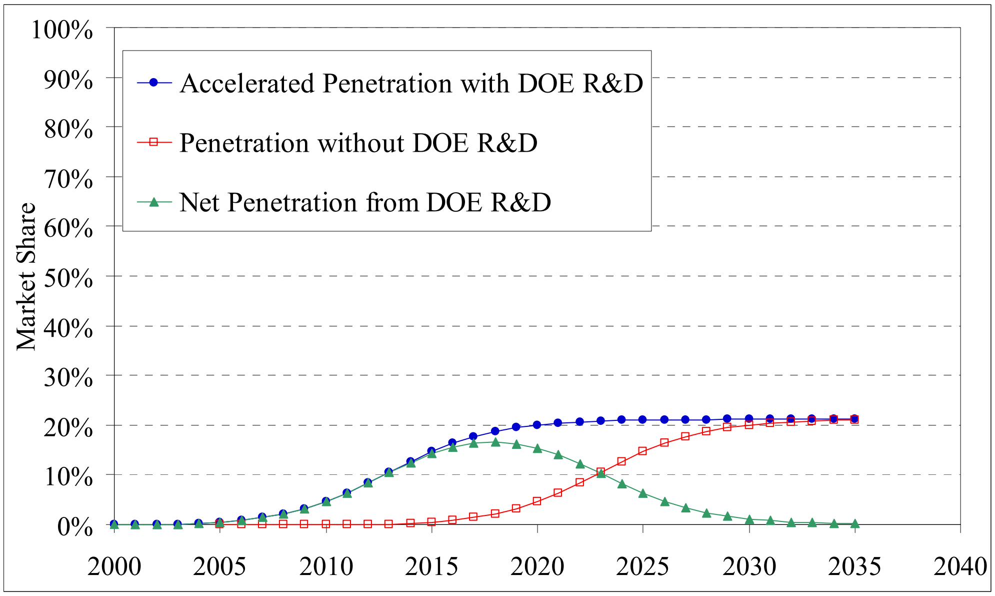

Figure A-10.2. Market Penetration Curve for Residential HVAC Distribution Systems (existing construction)

Project/Technology Consumer Costs (PNNL Estimate):

- Cost of Conventional Technology: $0.00
- Cost of BT Technology: $480
- Incremental Cost: $480/residence.

Residential HVAC Distribution Systems – New Construction

This technology, ducts in the conditioned space, and four other projects addressing the insulation issues associated with ducts,[d] will reduce the energy liabilities associated with residential ductwork. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in heating, cooling, and ventilation to the estimated consumption per square foot within new single-family buildings. We assumed that ventilation consumption and savings were included in the heating and cooling consumption and savings.

The per-square-foot energy-savings level were then aggregated to a project total based on a forecast of single-family building square feet and an estimated market penetration curve.

Performance Objective for New Construction:

- Displaced Technology: Current duct work, with the performance outlined in Table A-10.2.
- Performance Target: Table A-10.2 shows the reductions in HVAC end-use energy consumption that were assumed for FY 2004.

[d] E-mail from Esher Kweller, former project manager, to Dave Belzer, November 8, 2001.

Table A-10.2. Reductions in HVAC Energy Use for Residential Distribution Systems (new construction)

End Use	Percentage Reduction in Energy Consumption
Heating	17.2*
Cooling	8.7**

* Conventional design with R-8 duct insulation has a seasonal heating efficiency of ~80% and ~72% (average 76%) with R-4 duct insulation, while ducts in the conditioned space have a seasonal heating efficiency of ~94%;(4) therefore, the percentage reduction in heating energy consumption in single-family buildings with ducts is 19.1% (1 – 76%/94%). Of new residential construction, ~90% use ducts.(3) Therefore, the overall per building heating savings are 17.2% (19.1% * 90%).
** Conventional design with R-8 duct insulation has a seasonal cooling efficiency of ~90% and ~87% with R-4 duct insulation (average 88.5%), while ducts in the conditioned space have a cooling seasonal efficiency of ~98%%.(4) Therefore, the percentage reduction in cooling energy consumption in single-family buildings with ducts is 9.7% (1 – 90%/98%). Of new residential construction, ~90% use ducts.(3) Therefore, the overall per building cooling savings are 8.7% (9.7% * 90%).

Market Penetration for New Construction:

- **Target Market**: New single-family units in all climate zones.
- **Market Introduction**: 2004; this innovation is assumed not to occur without the DOE project.
- **Market Penetration Goal**: 20% of new single-family units by 2020 (see Figure A-10.3).

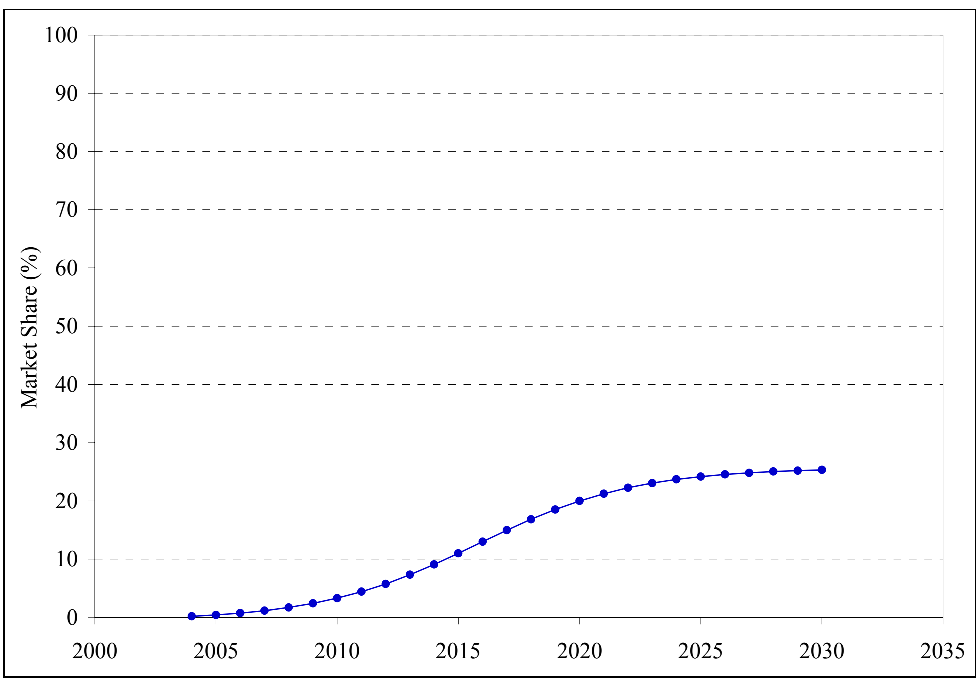

Figure A-10.3. Market Penetration Curve for Residential HVAC Distribution Systems (new construction)

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology:** $0.00
- **Cost of BT Technology:** $1000
- **Incremental Cost:** $1000/residence

Advanced Electric Heat Pump Water Heaters

This technology will increase the efficiency of residential and commercial electric water heating equipment and reduce peak energy use. The purpose of this program is to improve the cost effectiveness of heat pump water heaters mainly through lower capital costs. PNNL used BESET to determine this project's energy savings.

Performance Objective:

- **Displaced Technology:** Current electric water heater technology with an EF of .93.
- **Performance Target:** 1.8 energy factor.

Market Penetration:

- **Target Market:** Residential and commercial.
- **Market Introduction:** 2005; this project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal:** 6% by 2015 and 10% by 2020 (see Figure A-10.4).

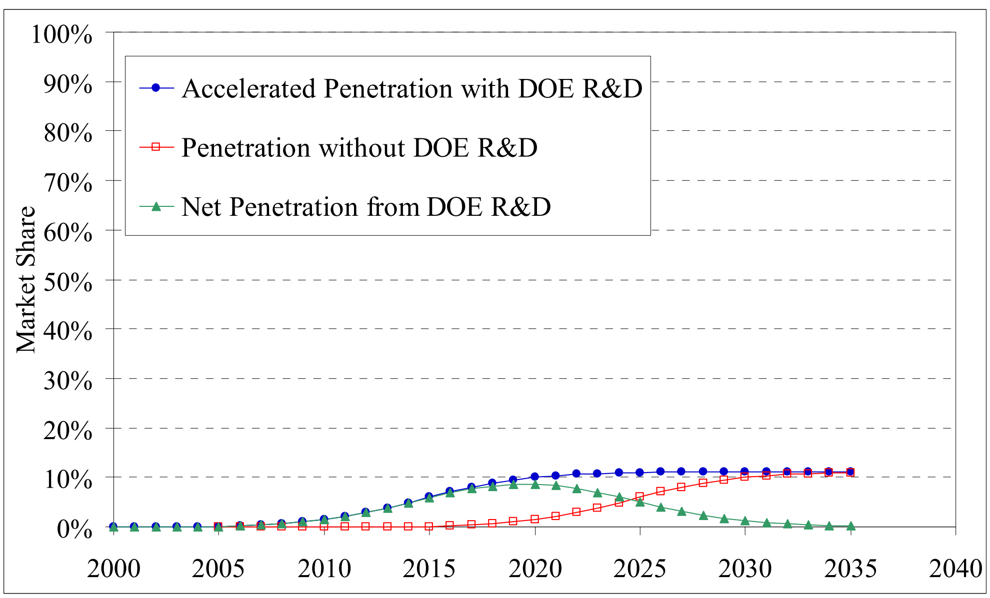

Figure A-10.4. Market Penetration Curve for Advanced Electric Heat Pump Water Heaters

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology:** $350
- **Cost of BT Technology:** $1025
- **Incremental Cost:** $675/unit.

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Refrigerant Pressure Charge Meters and COP Meters

This technology will increase the efficiency of residential and commercial space conditioning equipment and reduce peak energy use. Most air conditioning units and heat pumps have an improper refrigerant charge level or other issue resulting in a COP that is lower that design. These meters will inform the homeowner or business owner of the current state of charge or performance of their space conditioning equipment and ultimately the increased cost. Given this information, that is currently not readily available, it is expected that prudent owners will get the situation corrected. PNNL determined this project's energy savings by using BESET and applying overall percentage reductions in vapor compression heating and cooling energy consumption.

Performance Objective:

- **Displaced Technology:** None, because this technology an addition to both existing and future technologies. It provides a service not previously available.
- **Performance Target:** Table A10.3 shows the assumed reductions in HVAC end-use energy consumption for FY 2004.

Table A-10.3. Assumed Reductions in Energy Use for Refrigerant Pressure Charge Meters and COP Meters

End Use	Percentage Reduction in Energy Consumption
Residential Heat Pump Heating	23.9*
All Residential Cooling (includes heat pumps)	23.9
Commercial Heat Pump Heating	12.0**
Commercial Vapor Compression Cooling (includes heat pumps and excludes chillers)	12.0

* This value is based on a frequency distribution of undercharging and overcharging and on an efficiency impact associated with each level of undercharging and overcharging. http://www.proctoreng.com/checkme/technical.html.

** While the impact of undercharging and overcharging in commercial equipment is roughly the same as residential equipment, the frequency of undercharging and overcharging is believed to be about half that in residential equipment.

Market Penetration (PNNL estimates):

- **Market Introduction:** 2005; PNNL assumed this project accelerated the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goals:** 50% of all applicable residential units by 2020 and 90% of all applicable commercial units by 2020 (see Figures A-10.5 and A-10.6).

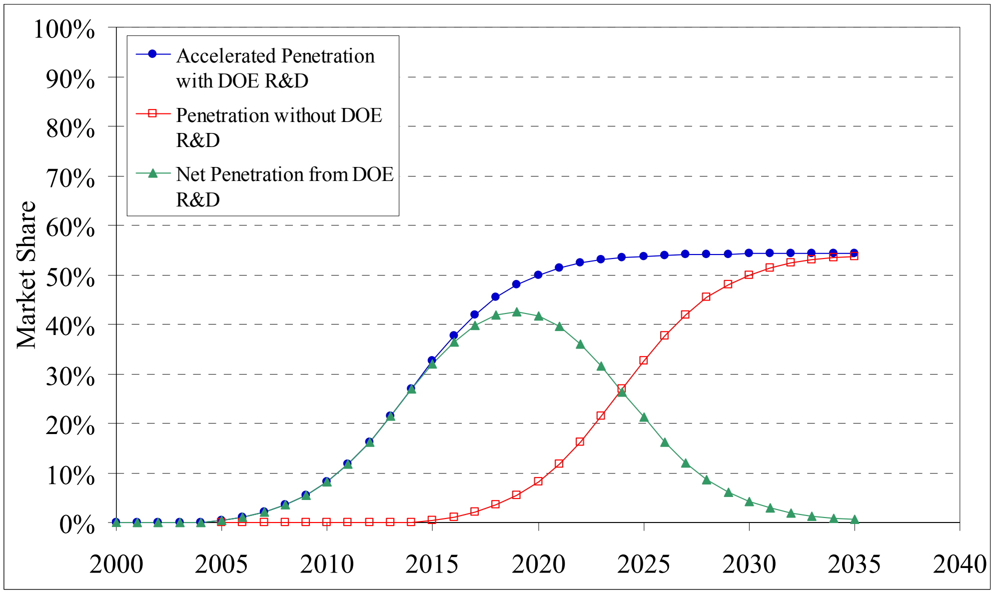

Figure A-10.5. Residential Market Penetration Curves for COP and Refrigerant Pressure Change Meters

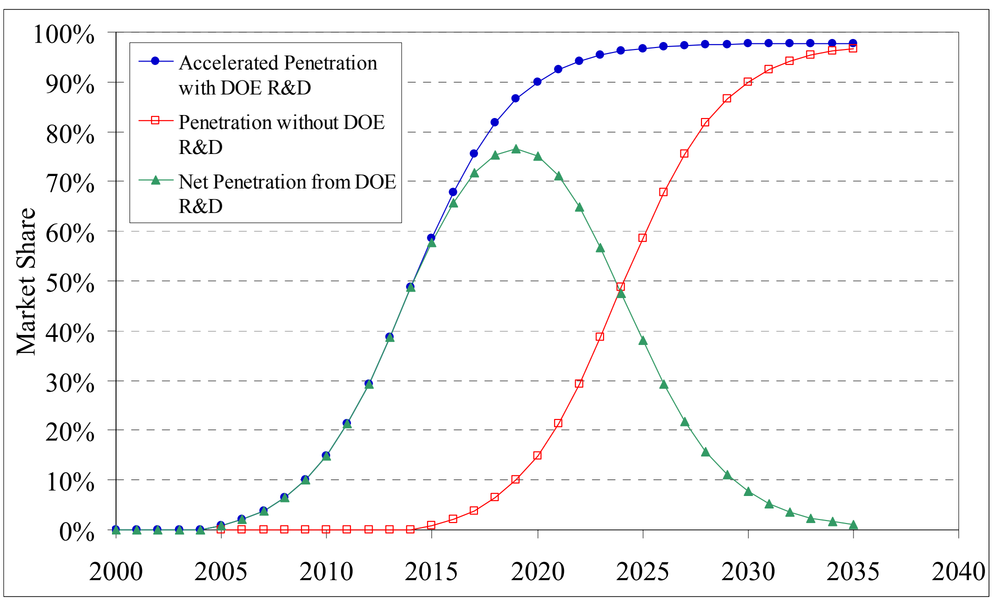

Figure A-10.6. Commercial Market Penetration Curves for Refrigerant and COP Meters

A.10 Space Conditioning and Refrigeration R&D

Emerging Technologies Decision Unit

Project/Technology Consumer Costs (PNNL estimates):

- Cost of Conventional Technology: $0.00.
- Cost of BT Technology: $100.00.
- Incremental Cost: $100.00.

Non-Energy Benefits:

- Reduced carbon emissions
- Economic benefits to the private sector
- Reduced pollution from leaking refrigerant
- Improved indoor air quality from better humidity control.

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Space Conditioning and Refrigeration: Refrigeration Program* (internal BTS document).

(2) Arthur D. Little, Inc. 1996 *Energy Savings Potential for Commercial Refrigeration Equipment.* Reference 46230-00. Cambridge, Massachusetts.

(3) Belzer, D.B and L.E. Wrench. 1997. *End-Use Consumption Estimates for U.S. Commercial Buildings, 1992*. PNNL-11514, Pacific Northwest National Laboratory, Richland, Washington.

(4) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 1, Upton, New York.

(5) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 4, Upton, New York, p.10.

(6) Brookhaven National Laboratory. 2001. *Better Duct Systems for Home Heating and Cooling*. BNL-68167, Vol. 3, Upton, New York, p.1.

A.11 Appliances and Emerging Technologies R&D

Emerging Technologies Decision Unit

Project Objective:[1]

This project helps manufacturers and utilities commercialize highly efficient appliances and equipment by providing the following assistance:

- Technology procurement to bring new technologies to market (late developmental work), which can bridge the gap between traditional R&D and mainstream deployment.
- To increase market share of emerging technologies and Energy Star technologies with very low market penetration, via independent third-party evaluation and verification of highly efficient technologies using field studies and demonstrations.
- R&D on appliances not covered by other projects but offering significant energy-savings potential.

Long-Term Goals :[1]

The project's long-term goal is to transform key energy product markets by working with industry partners to commercialize highly efficient technologies. Once established in the mainstream market, the technologies can become the basis for other approaches, such as Energy Star labeling or minimum efficiency standards.

Market Segment:

Target Market

- Market Description: The market includes residential and commercial building technologies, with emphasis on appliances and water heating.
- Size of Market: The market size depends on the various equipment:
  - Heat Pump Water Heaters: 13.6 million existing homes of the potential 44 million homes with electric resistance water heaters and ~40% of new homes. Limited, but initial market, for light commercial.
  - Gas-Condensing Water Heaters: ~20 million existing homes of the potential 60 million homes and ~40% of new homes.
  - Rooftop Air Conditioners: One of the most widely used technologies with greatest commercial space conditioning energy use; over a million tons sold in 1998.
  - Residential Can Lights: An estimated 22 million incandescent can fixtures sold in 2001.

Appliances and Emerging Technologies R&D

Project Type: Equipment efficiency

Target Market: All sectors, all climate zones

End Uses: Water heaters, lighting, and space cooling

Unit of Measurement: Efficiency of specific equipment type

Modeling Tool: NEMS-PNNL (heat pump water heater, rooftop air conditioner, gas-condensing water heater) and BESET (recessed can lights and R-lamps)

Project Manager: Jim Brodrick

Website: www.eren.doe.gov/buildings/emergingtech/index.html

♦♦♦♦♦♦♦♦♦♦♦♦

FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
4.7	11.2	77.1	127.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.084	0.207	1.537	2.357

Consumer Cost Savings (million $):

2004	2005	2010	2020
33	78	623	1143

– **Reflector CFLs (R-lamps):** ~125 million parabolic/reflector lamps sold to the residential market.

Methodology

PNNL modeled the lighting projects, recessed cans and R-lamps, with BESET and others using NEMS-PNNL. Key inputs and output for emerging technology's heat pump water heaters, roof top air-conditioners, and gas-condensing water heaters are described in the following sections.

NEMS Modeling of Emerging Technologies

PNNL modified the NEMS-PNNL residential model to represent heat pump water heaters and condensing gas water heaters and used the NEMS-PNNL commercial model for high-efficiency rooftop air conditioners. We modified several NEMS input files (RTEKTY.txt for residential, KTECH.wk1 for commercial) to produce the NEMS-PNNL results for each characterized technology. The baseline assumptions made by EIA, the cost and performance attributes of the BT-sponsored technologies, and the resulting market shares for these most energy-efficient technologies are documented in the following sections. For a few appliances, some changes were made in EIA's baseline assumptions; the reasons for these changes are briefly discussed.

General Methodology

For FY 2004, the water heater technologies funded by the Emerging Technologies project were modeled only in the residential model. The residential model uses a logit specification to estimate the market shares of specific technologies for a given type of appliance. For each appliance, two parameters generally influence how consumers value the tradeoff between the initial purchase cost versus the annual operating cost of the appliance. The annual operating cost depends on the energy efficiency of each technology (or "model") and the price of energy.

Heat Pump Water Heater

The purpose of this project is to expand the market for heat pump water heaters. Field testing, data collection, workshops, and potentially volume purchasing are elements of this project.

- **Market Introduction:** 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- **Performance Target:** 2.47 energy factor.
- **Penetration Target:** 10% by 2015.
- **Installed Cost:** Initial installation cost of $700, decreasing to $650 in 2006.
- **Lifetime:** 10 years.

The input file used for *Annual Energy Outlook 2001*[2] includes several categories of heat pump water heaters, two having installed costs of >$1,000. With the discount rates used in *Annual Energy Outlook 2001* for electric water heaters, only a very small number of the $1,025 units are predicted to be sold (no higher-costs unit). A more moderately priced heat pump unit is assumed to become available in 2005, with a cost of $900 and an energy factor of 2.0. By 2015, the cost of this unit is assumed to fall to $800 and the energy factor to increase to 2.2.

The original *Annual Energy Outlook 2001* input file does not reflect the pending water heater standards that are scheduled to take effect in 2004. Two modifications were made to account for these standards (shown at the top of Table A-11.1):

1. Technology #1 (see Table A-11.1) was assumed to be unavailable after 2003 and therefore was dropped from the list of technologies available to consumers in the GPRA FY 2004 time horizon.

2. The efficiency for technology #2 was changed to 0.89 with an unchanged cost (see revised characteristics under technology labeled #2a in Table A-11.1).

Table A-11.1. Key NEMS-PNNL Inputs for Electric Water Heaters

Technology	Start Year	End Year	Energy Factor	Installed Cost	Type
1	1997	2003	0.86	$350	Resistance
2	1997	2003	0.88	$350	Resistance
2a	2003	2020	0.89	$350	Resistance
3	1997	2020	0.95	$575	Resistance
4	1997	2020	2.60	$1,025	Heat Pump*
5	1997	2020	2.00	$2,600	Heat Pump
6	1997	2020	0.90	$360	Resistance
7	2005	2020	0.96	$475	Resistance
8	2004	2009	2.47	$700	Heat Pump**
9	2015	2020	0.90	$400	Resistance
10	2015	2020	0.96	$425	Resistance
11	2006	2020	2.47	$650	Heat Pump**

* Inexplicably, the lower-cost unit is assumed to have a higher efficiency.
** Appliances and Emerging Technologies project.

The Appliances and Emerging Technologies project is assumed to lead to a more rapid commercialization of a moderately priced heat pump water heater, first available in 2003. However, the project's principal impact is to achieve a lower cost than the unit assumed to be introduced in 2005 in the *Annual Energy Outlook 2001* base case. As Table A-11.1 shows, the heat pump water heater units supported by emerging technologies are assumed initially to have energy efficiency rating of 2.47 and an installed cost of $700.[e] By 2006, further development will yield a unit with the same energy factor (2.47) at lower cost ($650).

One issue related to assessing benefits of this technology with the NEMS-PNNL model is the appropriate discount rate to use. The logit parameters in the NEMS-PNNL model related to the choice of electric water heaters are -0.0162 (Beta1) and -0.0195 (Beta2), implying a discount

[e] The influence of emerging technologies research is assumed to reduce the unit from $900 (Annual Energy Outlook 2001base case) to $700.

rate of ~83%.[f] At this discount rate, the high initial cost of the heat pump water heater, even with its much higher efficiency, discourages most consumers from choosing this technology. A more robust assessment of the project is obtained by assuming that the ongoing Energy Star project for water heaters provides impetus for increased market acceptance of the heat pump water heater.[g] In this scenario, the changes in the discount rates assumed for Energy Star project are combined with the introduction of the (lower-cost) heat pump water heater.

The *Annual Energy Outlook 2001* baseline parameters that determined the market share for electric water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0162}{-0.0195} \approx discount\ rate = 83\%$$

With the support of the Appliances and Emerging Technologies and the Energy Star projects, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0072}{-0.0195} \approx discount\ rate^{E-Star} = 37\%$$

As Table A.11.2 shows, the lower discount rates generate much higher penetrations of the heat pump water heater, ultimately reaching nearly 25% of sales by 2010. While Table A-11.2 displays the shares for only new homes, the shares for the replacement market are similar.

The project's energy savings were calculated as the difference between NEMS-PNNL model runs that do the following:

1. Include the heat pump waters assumed in the AEO base case.
2. Substitute the lower-cost units assumed to stem from the Emerging Technologies project.
3. Assume Energy Star influence on deploying technology such that discount rate is reduced for water heaters.[h]

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[f] Within NEMS-PNNL, the two modeling parameters determining the discount rate are labeled Beta1 and Beta2. Beta1 is used as a multiplicative factor with the initial cost of the appliance. Beta2 is used to multiply the annual energy cost. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for the specific appliance.

[g] Market transformation projects, such as Energy Star, attempt to accelerate market penetration of existing high-efficiency technologies. From a modeling standpoint, these efforts translate into reducing the consumer's discount rate for these energy-efficient products. See the documentation specific to Energy Star project for more information.

[h] In both runs, the adjustments to the discount rate (via the Beta1 coefficient) were the same as those used in evaluating the Energy Star project for water heaters. The assumption of an ongoing Energy Star project raises the question of whether the Energy Star project should receive some of the credit for energy savings from this technology. No clear methodology exists for decomposing the benefits between applied R&D project and market conditioning activities. If such an attribution must be made for the

Table A-11.2. NEMS-PNNL Results for Heat Pump Water Heaters (national market shares[i] for new single-family homes)

Year	Market Share with *Annual Energy Outlook 2001* Discount Rate	Market Share with Adjusted NEMS-PNNL Discount Rates
2004	0.024	0.040
2005	0.012	0.031
2006	0.012	0.050
2007	0.012	0.077
2008	0.012	0.116
2010	0.028	0.239
2015	0.047	0.241
2020	0.048	0.243

In essence, the heat pump water heaters' savings were calculated as the difference between an Energy Star project with and without the units developed under the Appliances and Emerging Technologies project. (The Energy Star project characterization, in Appendix B, contains further discussion of the savings from the Energy Star project without these lower-cost heat pumps.)

Gas-Condensing Water Heater

- **Market Introduction**: 2002; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- **Performance Target**: Energy factor of 0.80.
- **Penetration Target**: 9% to 10% by 2020.
- **Installed Cost**: Incremental cost of $150 to $200 over conventional technology. Estimated from a study that gives a price of $700.[4]
- **Lifetime**: 10 years.

The original *Annual Energy Outlook 2001*[2] input file does not reflect the pending water heater standards that are scheduled to take effect in 2004. To account for these standards in the gas water heater market, the technologies with energy factors <0.60 (0.54 and 0.58) were specified to be unavailable after 2003. These NEMS-PNNL modifications are shown in the top two lines of Table A.11.3. The EIA includes a high-efficiency condensing gas water heater in its menu of technology choices for the *Annual Energy Outlook 2001*. As Table A-11.3 shows, these units have very high costs. Not surprisingly, the model yields negligible market shares for this technology.

The Appliances and Emerging Technologies project is assumed to lead to the commercialization of a moderately priced condensing gas water heater, first available in 2005. As Table A-11.3 shows, the units are assumed initially to have an energy efficiency rating of 0.8 and cost $550

GPRA process, 70% of the savings are proposed to be assigned to the Appliances and Emerging Technologies project and 30% to Energy Star.

[i] The market shares in this discussion pertain only to electric water heaters.

Table A-11.3. Key NEMS-PNNL Inputs for Gas Water Heaters

Equipment Type	First Year Available	Last Year Available	Efficiency	Installed Cost	Type of Technology
3	1997	2004	0.6	$400	Noncondensing
3	2005	2020	0.6	$375	Noncondensing
4	1997	2004	0.86	$2,360	Condensing
4	2005	2014	0.86	$2,000	Condensing
4	2015	2020	0.86	$1,800	Condensing
5	2005	2014	0.63	$450	Noncondensing
5	2015	2020	0.63	$425	Noncondensing
6	2015	2020	0.7	$500	Noncondensing
26	2005	2020	0.8	$500	*Condensing
27	2010	2020	0.8	$475	*Condensing
*Emerging Technologies Project unit.					

(installed). By 2010, further development is assumed to yield a unit with a slightly lower cost ($525).

As with the heat pump water heater, an issue related to assessing benefits with the NEMS-PNNL model is the appropriate discount rate to employ. The logit parameters in the NEMS-PNNL model related to the choice of gas water heaters are -0.05393 (Beta1) and -0.1136 (Beta2), implying a discount rate of ~47%. At this discount rate, the higher initial cost of the BT-sponsored condensing gas water heater, even with its much higher efficiency, discourages most consumers from choosing this technology. The NEMS-PNNL results shown in column 2 of Table A.11.4 show that the market share only reaches ~1%, even with the lower-cost second-generation unit assumed in the analysis.

As with the heat pump water heater, a more robust assessment of the project is obtained by assuming that the ongoing Energy Star project for water heaters provides impetus for increased market acceptance of the condensing gas water heater. In this scenario, the changes in the discount rates assumed for Energy Star project are combined with the introduction of the (lower-cost) condensing gas water heater.

The *Annual Energy Outlook* baseline parameters that determined the market share for gas water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0539}{-0.1136} \approx discount\ rate = 47\%$$

With the support of the Appliances and Emerging Technologies and the Energy Star projects, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0359}{-0.1136} \approx discount\ rate^{E-Star} = 32\%$$

As Table A.11.4 shows, the lower discount rates generate much higher penetrations of the condensing water heater, ultimately reaching nearly 10% of sales by 2010. The inputs in *Annual Energy Outlook 2001* assume the introduction of a high efficiency noncondensing unit in 2015. This assumption is the principal explanation for why the share of the condensing unit drops between 2010 and 2020. While Table A-11.4 shows the shares for only new homes; the shares for the replacement market are similar.

Table A-11.4. NEMS-PNNL Results for Energy Star Gas Water Heaters (national market shares for new single-family homes)

Year	Market Share with *Annual Energy Outlook 2001* Discount Rate	Market Share with NEMS-PNNL Adjusted Discount Rate
2005	0.003	0.009
2006	0.003	0.015
2007	0.003	0.024
2008	0.003	0.038
2010	0.011	0.129
2015	0.009	0.100
2020	0.010	0.106

Rooftop Air Conditioning

- **Market Introduction:** 2004; the National Research Council (acceleration-to-market) methodology was not applied to this technology because the impact was determined to be negligible. Given that the technology has only modest penetration (10%) by 2020 and only a few percent by 2010, the National Research Council methodology would not have a significant impact over the analysis period.
- **Performance Target:** An efficiency increase from 10.3 to 11.0 energy efficiency ratio for 65 to 135 kBtu/hr and from 9.7 to 10.8 for 135 to 240 kBtu/hr.
- **Penetration Target:** 10% of sales in 2020.
- **Lifetime:** 15 years.

The rooftop air conditioner project uses competitive procurements of large numbers of units to stimulate the production of high-efficiency equipment. The immediate goal is to get high-efficiency equipment installed in buildings owned by the federal government and other state and local agencies. A long-term, key outcome of the project is to provide incentives for manufacturers to reduce the cost of this equipment to all potential and private sector buyers.

With this long-term goal in mind, PNNL adjusted the assumed costs of high efficiency roof top air conditioners in the NEMS-PNNL commercial model to reflect the principal influence of this project. In NEMS-PNNL, two air conditioners were specified in the rooftop category—a baseline unit (energy efficiency ratio of 8.5) and a high-efficiency unit (energy efficiency ratio of 11.6). No subgroups were distinguished by capacity (e.g., 65 to 135 kBtu/hr vs. 135 to 240 kBtu/hr).[j]

For the GPRA analysis, the incremental cost was reduced by 40%, based on project goals. Given the proportion of the market assumed in the NEMS-PNNL to display high discount rates in the selection of equipment, this cost reduction yielded a 9% penetration of the high-efficiency unit in 2005. The penetration rate falls to 6% in 2010 possibly the result of a greater efficiency in the baseline units and/or lower energy costs.[k] By 2020, the proportion of the total stock using the high-efficiency unit is ~5%.

BESET Methodol*ogy*

The size of the target market is determined by the building stock, existing equipment market shares, and the turnover or replacement rate of existing equipment. The BT technology is assumed to compete only with "new" units (or equipment sales). For new buildings, all units are considered new. For existing buildings, only units scheduled for replacement are considered eligible for the BT technology. The BT technology is assumed not to replace a piece of equipment unless the equipment was going to be replaced anyway. The penetration rates for new buildings refer to the penetration into buildings built in 2004 and beyond. The penetration into existing buildings is the penetration into all buildings built before 2004.

Residential Can Lights

- Market Introduction: 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 10 years.
- Performance Target: Assumed efficacy of 51.3 lumens/watt. Actual project requirements should be similar to Energy Star, as Table A-11.5 shows. However, because incandescent lamps also have lower efficacies, the ratio between Energy Star compact fluorescent lamps and all incandescents was assumed to be the same regardless of type. See the Energy Star compact fluorescent lamp summary in Appendix B.

[j] PNNL developed an alternative technology spreadsheet to model the rooftop initiative in the Appliances and Emerging Technologies project. In the most recent version of NEMS-PNNL, the technology cost and performance inputs are in a spreadsheet, in which the user can adjust the *incremental* cost between baseline unit and the high-efficiency unit.

[k] The precise reasons for this behavior have not been thoroughly investigated.

Table A-11.5. Performance Targets for Residential Can Lights

Lamp Power (watts) and Configuration	Minimum Efficacy: Lumens/watt*
Reflector Lamp:	
Lamp power <20	33
Lamp power >=20	40
*Based on initial lumen date.	

- **Penetration Target:** 30% of recessed can lights by 2008. The 30% penetration rate was assumed to occur across all fixtures in a home; that is, a home was assumed to have either all CFL cans or all incandescent cans. In 2020, 7% of the incandescent market will be recessed can lights[3] (see Figure A-11.1); thus, this represents 2.1% of all incandescents.
- **Lifetime:** 30 years.

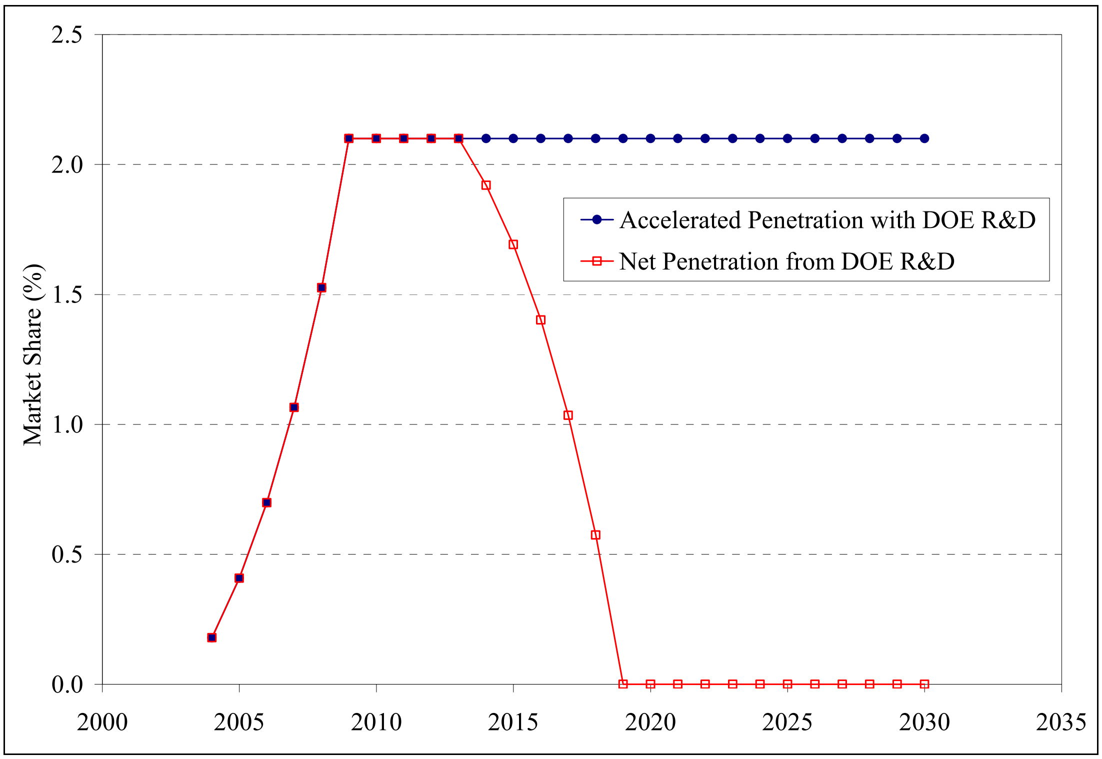

Figure A-11.1. Market Penetration Curve for Residential Can Lights as a Percentage of all Incandescents

R-Lamps

- **Market Introduction:** 2003; these projects were assumed to accelerate the introduction of these technologies into the marketplace by 4 years.
- **Performance Target:** Assumed efficacy of 51.3 lumen/watt. Actual project requirements should be similar to Energy Star, as Table A-11.6 shows. However, because incandescent reflector lamps also have lower efficacies, the ratio between Energy Star compact

fluorescent lamps and all incandescents were assumed to be the same regardless of type. See the Energy Star compact fluorescent lamp summary in Appendix B.

Table A-11.6. Performance Targets for R-Lamps

Lamp Power (watts) and Configuration	Minimum Efficacy: Lumens/watt*
Reflector Lamp:	
Lamp power <20	33
Lamp power >=20	40
* Based on initial lumen date.	

- **Penetration Target:** The goal is to replace 0.87% of all incandescent lighting by 2010. To achieve this goal, an 8.47% sales fraction must be reached with a long-term installed base of 27%, which has consumption roughly equivalent to a 10% installed base in the most energy-intensive fixtures (0.87% = 8.47% * 10.3%). This penetration rate is based on a 4-year compact fluorescent lamp life and a 1-year incandescent reflector life. (The 1-year life for incandescents is longer than the average life of an incandescent lamp; however, integer life inputs are required for BESET, so the ratio between incandescent and fluorescent lights was adjusted appropriately to account for this.) In 2008, 10.3% of the incandescent market will be reflector lights[5] (see Figure A-11.2).
- **Installed Cost:** $14/compact fluorescent lamp reflector lamp.
- **Lifetime:** 8,000 hours (4 years for BESET).

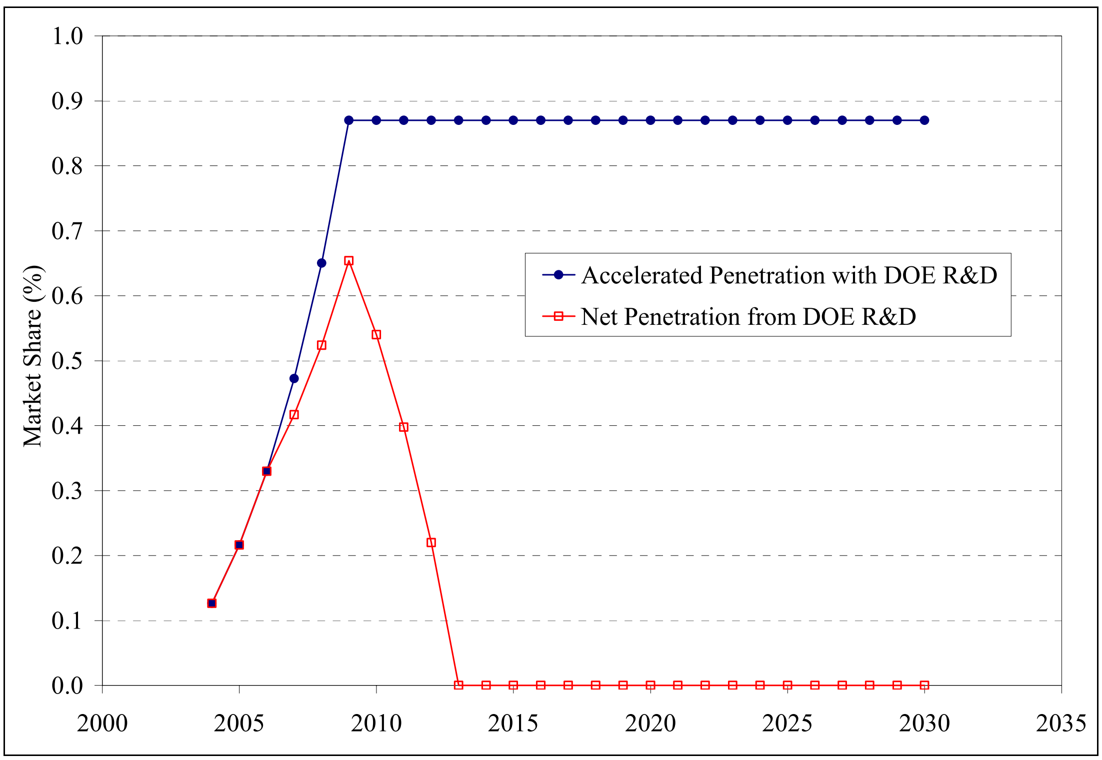

Figure A-11.2. Market Penetration Curve for R-Lamps

Non-Energy Benefits:

- Reduced carbon emissions
- Economic benefits to private sector.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Appliances and Emerging Technology Program* (internal BTS document).
(2) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.
(3) Estimated from http://enduse.lbl.gov/Info/LBNL-39102.pdf, p.19.
(4) Gordon, K.L., and M.R. Ledbetter. 2001. *Technology Procurement Screening Study*. Pacific Northwest National Laboratory, Richland, Washington.
(5) The Freedonia Group, Inc. 1999. *Lamps in the United States to 2003*. Cleveland, Ohio. (See the following sections: "Introduction," "Executive Summary," "Market Environment," "Supply and Demand," "Incandescent Lamps," "Electrical Discharge," and "Lamp Markets.")

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Project Objective:[1]

The project's objective is to promote the research and development and deployment of energy-efficient windows. Because the fenestration field is less suited to national standards and has a growing international market, significant investments are needed to establish a technical basis for performance standards recognized for scientific excellence. On this basis, the project helps develop the credible rating, certification projects, and design tools to develop and apply efficient windows. The project also conducts R&D on high-performance windows, including electrochromic technology, and durable spectrally selective glazing.

Long-Term Goals:[1]

The project's specific long-term goals are as follows:

- **National**: Change windows from net energy losers to net energy providers across the U.S.
- **Industry**: Strengthen market position of U.S. industry in global markets.
- **Owners**: Provide cost-effective savings with comfort, productivity, and amenity.

Methodology

PNNL calculated the energy savings for building envelope projects by simulating the effect of an envelope technology using the FEDS[2] model for many different building types, sizes, vintages, and locations and then using NEMS-PNNL to calculate national impacts. PNNL calculated the heating and cooling loads for each building with and without evaluating the envelope technology. We then used the changes in the heating and cooling loads to modify the heating and cooling envelope 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 representative. Specific project inputs are characterized below for the project's two primary technologies: electrochromic windows and superwindows.

Building Envelope R&D: Window Technologies

Project Type:
Envelope

Target Market:
All sectors in all climate zones

End Uses:
Windows

Unit of Measurement:
Change in heating and cooling loads (based on change in U-factor and shading coefficient)

Modeling Tool:
NEMS-PNNL envelope

Project Manager:
Marc LaFrance

♦♦♦♦♦♦♦♦♦♦♦♦

FY2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
11.5	18.2	70.7	250.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.202	0.327	1.31	4.35

Consumer Cost Savings (million $):

2004	2005	2010	2020
78	122	501	1940

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Electrochromic Windows[1]

This project develops commercially viable advanced electrochromic windows using competing producers. With a focus on electrochromic research, the project's objective is to reward the marketplace for industry's investments in researching, developing, and deploying energy-efficient windows.

Market Segment:

Performance Objective:

- **Displaced Technology:** Conventional double-glazed, low-emissivity windows.
- **Performance Target:** Reduce unwanted heat gains and losses and perimeter lighting (See Table A-12.1).
- **Performance Parameters:** Estimated savings per building were determined by simulating all commercial building types in all climate zones. National impacts were determined using NEMS-PNNL (Table A-12.1).

Table A-12.1. Performance Targets for Electrochromic Windows

Parameter	Value	Units
Maximum Shading Coefficient	0.4 (heating)	Dimensionless
Minimum Shading Coefficient	0.1 (cooling)	Dimensionless
U-value	0.25	Btu/h • ft^2• ^oF
Lighting Reduction	30	% of lighting energy

Target Market

- **Market Description:** [1] The market includes new and existing commercial building types in all climate zones.
- **Size of Market:** ~500 million square feet of windows for commercial buildings.
- **Market Introduction:** The market introduction is targeted for the end of FY 2003 for electrochromic windows in commercial applications. According to a recent study, Electrochromic glazings are currently commercially available in Germany and are anticipated to be available in the US market in 2003[2]. This project was assumed to accelerate the introduction of this technology into the marketplace by 10 years.
- **Market Penetration Goal:** See Table A-12.2.

Table A-12.2. Market Penetration Goals for Electrochromic Windows

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
All Commercial	New	All	2.0	20.0	50.0
All Commercial	Existing	All	1.8	17.2	43.2

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Project/Technology Consumer Costs:

- **Incremental Cost of BT Technology:** Incremental investment costs were developed assuming a 10-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $10).

Superwindows

The project is developing commercially viable advanced technologies from competing producers and providing research support to Energy Star and Efficient Window Collaborative projects. One project objective is to double the average energy efficiency of windows sold and establish universal National Fenestration Rating Council ratings based on credible International Standards Organization standards.

Market Segment:

Performance Objective:

- **Displaced Technology:** Conventional double-glazed, low-emissivity windows with a U-value of 0.357 Btu/h • ft^2 • ^{o}F and a shading coefficient of 0.52.
- **Performance Target:** Reduce unwanted heat gains and losses.
- **Performance Parameters:** Two superwindow technologies were used: northern superwindows in heating dominated climates (heating-degree days >4500) and southern superwindows in cooling dominated climates (heating-degree days <4500). The estimated savings per building were determined by simulating residential buildings in all climate zones. National impacts were determined using NEMS-PNNL (see Table A-12.3).

Table A-12.3. Performance Targets for Superwindows

Window	Parameter	Value	Units
Northern Superwindow	Shading Coefficient	0.7 (heating season) 0.3 (cooling season)	Dimensionless
	U-value	0.1	Btu/h • ft^2 • ^{o}F
Southern Superwindow	Shading Coefficient	0.15 (all seasons)	Dimensionless
	U-value	0.2	Btu/h • ft^2 • ^{o}F

Target Market

- **Market Description:** (1) New and existing residential units in all climate zones.
- **Size of Market:** (1) ~55 million manufactured units sold each year for residential and light commercial.
- **Market Introduction:** 1999(3); PNNL assumes that this project accelerates the introduction for these technologies, into the marketplace by 10 years.
- **Market Penetration Goal:** See Table A-12.4.

A.12 Building Envelope R&D: Window Technologies

Emerging Technologies Decision Unit

Table A-12.4. Market Penetration Goals for Superwindows

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
Residential	New	All	3.0	65	85.0
Residential	Existing	All	1.5	33	43.2

Project/Technology Consumer Costs:[(4)]

- **Incremental Cost of BT Technology:** Incremental investment costs were developed assuming a 20-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $20).

Non-Energy Benefits:[(1)]

- Reduced utility and building peak loads
- Reduced HVAC requirements and first costs
- Improved indoor comfort and aesthetics.

Source:

(1) *FY 2002 Budget Request - Data Bucket Report for Building Envelope: Windows Program* (internal BT document).

(2) Lawrence Berkeley National Laboratory, et. al. 2002. *Active Load Management with Advanced Window Wall Systems: Research and Industry Perspectives.* LBNL-50855. June 2002. Berkeley, California.

(3) Southwall Technologies. "Superglass Quad," product description accessed from website. http://www.southwall.com/products/superglass.html. Accessed March 31, 2003.

(4) Pacific Northwest National Laboratory. 2002. *Facility Energy Decision System User's Guide, Release 5.0.* PNNL-10542, Rev. 6, Richland, Washington.

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Project Objective:[1]

This project improves envelope performance through advanced technology and increased understanding of the basic processes governing envelope performance. Building envelopes, which influence electric lighting requirements, are the primary factors governing buildings' heating, cooling, and ventilation requirements. Because building envelopes impact 53% of building energy use, improving the materials, components, and systems that make up building envelopes can save substantial energy.

This project performs research on energy-efficient, sustainable, low-cost, and thermal insulation and building envelope materials and structures. The project develops laboratory, analytical, and field experiments and methodologies to characterize tools and testing for new or improved materials and systems. The project also provides accurate evaluation procedures.

Long-Term Goal:[1]

One of the project's long-term goal is to develop new building materials and systems that are cost-competitive for their application and are as environmentally benign and sustainable as possible. Another long-term goal involves developing a fundamental understanding of heat, air, and moisture transfer through building envelopes and insulation materials and applying the results to develop construction technologies to increase building energy efficiency.

Market Segment:

Performance Objective:

- Displaced Technology: This project develops technology to displace conventional wall and roof insulation and framing.
- Performance Target: The performance target is to reduce unwanted heat gains and losses and perimeter lighting.
- Performance Parameters: PNNL estimated savings per building for quick fill walls by simulating food sales, mercantile and service, warehouse, and other commercial building types and single-family residential buildings in all climate zones. For 30/30 roofs, all commercial buildings in all climate zones were considered. We used NEMS-PNNL to determine national impacts. This results in a roof insulation R-value parameter of 30 Btu/h • ft^2 • ^{o}F.

Building Envelope R&D: Thermal Insulation and Building Materials

Project Type:
Envelope

Target Market:
All sectors in all climate zones

End Uses:
Roofs and insulation

Unit of Measurement:
% change in heating and cooling load (based on change in envelope component u-value)

Modeling Tool:
NEMS-PNNL envelope

Project Manager:
Marc LaFrance

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FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.2	0.9	9.0	62.1

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.003	0.013	0.136	0.947

Consumer Cost Savings (million $):

2004	2005	2010	2020
1	6	61	419

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Target Market

- **Market Description:** [1] This project involves developing materials and building envelope structures that can be used in new residential and commercial buildings. Certain project elements also focus on retrofit strategies. The project activities are independent of region and household income.
- **Size of Market:** [1] The market size includes all new and retrofit residential and commercial construction and all building categories.

Methodology

PNNL calculated energy savings for building envelope projects by simulating the effect of an envelope technology using the FEDS[2] model for many different building types, sizes, vintages, and locations and then using NEMS-PNNL to calculate national impacts. We calculated the heating and cooling loads each building with and without evaluating the envelope technology. We then used the heating and cooling load changes to modify the heating and cooling envelope 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 representative. Specific project inputs are characterized below.

Quick Fill Walls

This technology involves applying environmentally friendly wall-insulating techniques.

Performance Objective:

- **Displaced Technology:** Conventional wall insulation and framing.
- **Performance Target:** Reduce unwanted heat gains and losses and perimeter lighting.
- **Performance Parameters:** Estimated savings per building were determined by simulating food sales, mercantile and service, warehouse, and other commercial building types and single-family residential buildings in all climate zones. National impacts were determined in NEMS-PNNL. This results in a wall insulation parameter of 36 Btu/h • ft^2 • ^oF.

Market Penetration:

- **Target Market:** Selected commercial and residential buildings in all climate zones.
- **Market Introduction:** 2004; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal:** See Table A-13.1.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Table A-13.1. Market Penetration Goals for Quick Fill Walls

Rate of Penetration (% of annual sales)				
Building Type	Vintage	Region	2010	2030
Food Sales, Mercantile and Service, Warehouse, and Other	New	All	1.5	7.6
Residential	New	All	2.3	11.5

R30 Insulation/30-Year Life Roofs

This technology involves applying advanced roofing techniques.

Performance Objective:

- **Displaced Technology**: Conventional roof insulation.
- **Unit of Measurement**: Cooling and heating load reductions for commercial buildings.
- **Performance Target**: Reduce unwanted heat gains and losses. .
- **Performance Parameters**: Estimated savings per building were determined by simulating all commercial building types in all climate zones. National impacts were determined in NEMS-PNNL. This results in a roof insulation R-value parameter of 30 Btu/h • ft^2 • ^oF.

Market Penetration:

- **Target Market**: All sectors in all climate zones.
- **Market Introduction**: 2010; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal**: See Table A-13.2.

Table A-13.2. Market Penetration Goals for R30 Insulation/30-Year Life Roofs

Rate of Penetration (% of annual sales)				
Building Type	Vintage	Region	2010	2030
All Commercial	New	All	0.6	50.5
All Commercial	Existing	All	0.4	30.2

Project/Technology Consumer Costs (PNNL Estimate):

- **Cost of Conventional Technology**: $0
- **Cost of BT Technology**: $0
- **Incremental Cost**: $0.

Moisture/Wet Insulation

This technology involves developing and applying insulation technology that does not lose its loft or insulating capability after becoming moist/wet and does not cost more than the conventional technology it is replacing.

A.13 Building Envelope R&D: Thermal Insulation and Building Materials

Emerging Technologies Decision Unit

Performance Objective:

- **Performance Target:** Reduce unwanted heat gains and losses by 10%.

Market Penetration

- **Target Market:** All residential buildings in all climate zones.
- **Market Introduction:** 2004; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology was not applied.
- **Market Penetration Goal:** See Table A-13.3.

Table A-13.3. Market Penetration Goal for Moisture/Wet Insulation

Rate of Penetration (% of annual sales)					
Building Type	Vintage	Region	2005	2020	2030
Residential	New	All	3.0	65.0	85.0
Residential	Existing	All	1.5	33.0	43.2

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 3-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $3).

Non-Energy Benefits:[1]

- Reduced construction and demolition waste
- Use of natural, recycled, and byproduct materials
- Reduced CO_2 emissions from improved energy efficiency
- Increased housing affordability from reduced energy consumption
- Improved comfort and indoor air quality from more moisture tolerant designs and controls
- Increased global competitiveness of U.S. industry.

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Building Envelope: Thermal Insulation and Buildings Materials Program* (internal BTS document).

(2) Pacific Northwest National Laboratory. 2002. *Facility Energy Decision System User's Guide, Release 5.0*. PNNL-10542, Rev. 3, Richland, Washington.

A.14 Analysis Tools and Design Strategies

Emerging Technologies Decision Unit

Project Objective:[1]

The Analysis Tools and Design Strategies project researches the interrelationship of energy systems and buildings energy performance, develops various building analysis tools to more accurately model energy use in new and existing buildings, and provides recommendations and strategies to cost effectively lower energy use and improve building performance. The project focuses on whole-building software tools for evaluating energy efficiency and renewable energy. The project also focuses on nonsoftware solutions such as improved standards, guidelines, and performance measurements, all of which bring about excellence in designing new buildings.

Long-Term Goal:[1]

The project's long-term goal is to improve energy designs for all building types through a number of widely used analytical tools and guidance documents.

Market Segment:

Performance Objective:[2]

- Displaced Technology: This technology displaces conventional design/building practice.
- Performance Target: By 2020, the performance target is to reduce heating and cooling loads by 50% in new construction and use energy analysis tools in the design of 60% of new commercial building square footage.

Target Market[2]

- Market Description: The market includes all new commercial and retrofit construction (particularly buildings with energy-use intensities >50% of the average energy-use intensity).
- Size of Market: The market size includes new commercial assembly, education, food sales, food service, lodging, health care, mercantile/service, and office buildings.
- Market Introduction: 1996; this activity was assumed not to occur without DOE funding; therefore, the National Research Council methodology (acceleration-to-market) was not applied.

Analysis Tools and Design Strategies

Project Type:
Whole building

Target Market:
New commercial buildings in all climate zones

End Uses:
All end uses and all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Dru Crawley

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FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0.1	0.3	3.7	41.4

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.002	0.006	0.073	0.757

Consumer Cost Savings (million $):

2004	2005	2010	2020
1	2	24	302

- **Market Penetration Goal:** The goal is to penetrate 70%[1] of new commercial and multifamily construction by 2020 in combination with the Commercial Buildings Technology R&D project. The share of the market penetration attributed to Analysis Tools and Design Strategies is shown on Figure A-14.1.

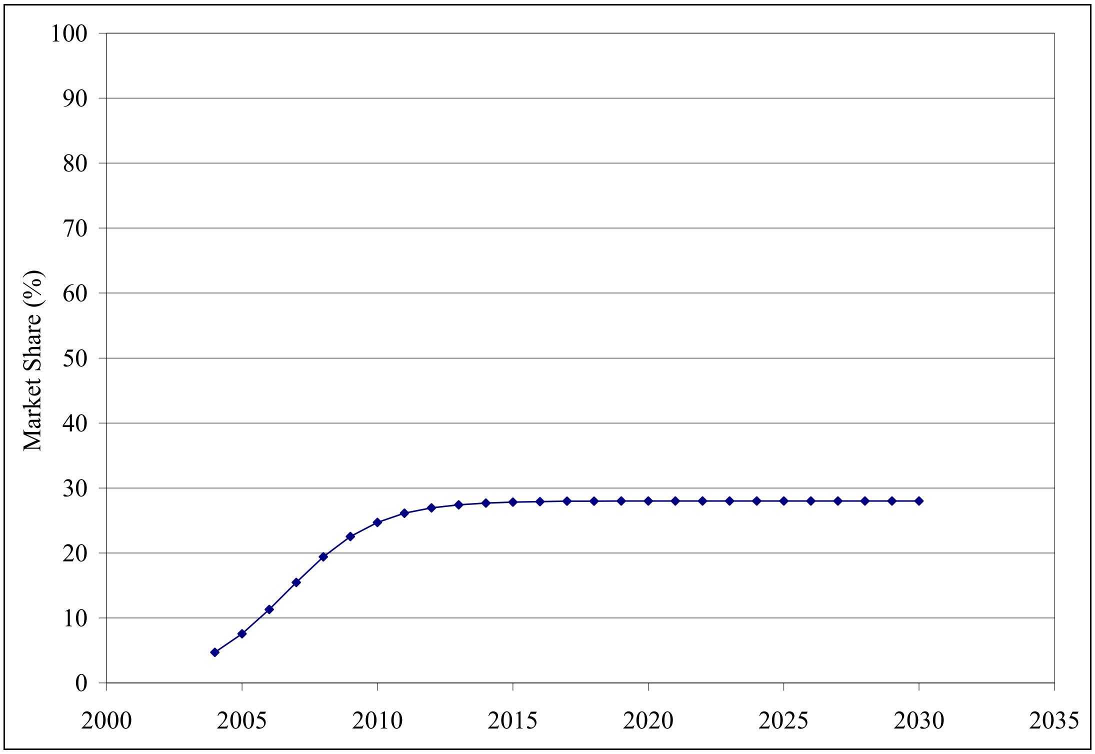

Figure A-14.1. Market Penetration Curve for Analysis Tools and Design Strategies

Methodology

PNNL used BESET to estimate energy savings. To simulate historical penetration rate patterns, we calculated penetration rates for all years before 2030 based on diffusion models, or "S curves" based on historical data. The diffusion models require only the maximum penetration in the final year and the year of entry into the market. Energy technology

[1] In its report, *Energy Research at DOE Was it Worth it?,* the NRC committee concluded that the 25% sustained market penetration estimated for DOE-2 (a software tool previously developed under this project), was overestimated, based on available data (NRC 2001). This conclusion would appear be in conflict with the assumed goals stated for this project. The Analysis Tools and Design Strategies project manager, however, maintains that tools currently in development should achieve the stated penetration goals in combination with the Commercial R&D project.

diffusion curves were estimated from historical data, and generic curves applicable to future technologies were developed.

Non-Energy Benefits:[1]

- Improved indoor environmental quality such as thermal comfort and ventilation adequacy
- Improved indoor air quality
- Fire safety
- Overall environmental sustainability (i.e., Green Buildings).

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for Analysis Tools and Design Strategies Program* (internal BTS document).

(2) Interview with the project manager, Dru Crawley, August 22, 2001.

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

Project Objective:[1]

The Equipment Standards and Analysis project achieves significant energy savings, consumer cost savings, and reduced air emissions through rule-making standards. The project also prescribes test procedures that measure energy efficiency and energy use and that estimate the annual operating cost of each appliance.

Long-Term Goal:[1]

The project's long-term goal is to set minimum national efficiency standards that lead to increases in the average efficiency of new building equipment.

Market Segment:

Target Market

- Market Description: The market includes all residential and commercial equipment covered by the appropriate legislation.[2,3]
- Size of Market: The market size includes all applicable residential and commercial equipment in the market to which legislation applies (Ovens/ranges and medical equipment, for example, are not covered).

Methodology

For FY 2004, the energy savings from equipment standards activities were primarily based on a PNNL screening analysis conducted in late 1999 and early 2000[4] to provide preliminary estimates of the potential energy savings from updated commercial equipment standards. We used the spreadsheet developed for this study to estimate the energy savings from various levels of standards for nearly 40 types of equipment covered by EPAct. The spreadsheet results were used to identify technologies that could achieve significant energy savings beyond the efficiency levels set in the recent ASHRAE 90.1-1999 publication.[5]

For FY 2004, the EPAct standards were assumed to continue with the technologies having the potential for additional energy savings. These technologies include boilers, three-phase residential-size cooling equipment, packaged terminal air conditioning, packaged terminal heat pump equipment, and large rooftop air-conditioning equipment. Energy-savings estimates for these technologies based on the spreadsheet are shown in the next section.

Equipment Standards and Analysis

Project Type:
Codes and standards for equipment efficiency

Target Market:
All sectors in all climate zones

End Uses:
All end uses and all fuel types

Unit of Measurement:
Efficiency of specific equipment

Modeling Tool:
NEMS-PNNL spreadsheet

Project Manager:
Carl Adams

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FY2004 Benefits

Primary Energy Savings (TBtu):

2004	2005	2010	2020
0	3.4	83.1	341.2

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.000	0.064	1.657	6.415

Consumer Cost Savings (million $):

2004	2005	2010	2020
0	22	552	2608

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

The FY 2004 savings for this project also included an estimate for revised standards for residential gas furnaces. This project was modeled in the NEMS-PNNL residential module. In the baseline version of the model used by EIA for its *Annual Energy Outlook 2001*,[7] a wide range of the furnace efficiencies was available: 78%, 80%, 84%, 88%, and 96%. To estimate energy savings from this potential standard the 78% and 80% efficiency levels were assumed to not meet the revised standard after 2007. Assuming that the new standard would be set at approximately 82%, an entry with this efficiency level was added to the list of technology options.[m] In addition, savings related to standards covering distribution transformers were calculated in a spreadsheet based on a 1992 study conducted by Geller and Nadel.[7]

Commercial Products

Based on the spreadsheet EPACT_SA.XLS (essentially identical to the spreadsheet installed on the BT website for public comment subsequent to the EPAct screening analysis), Tables A-15.1 and A-15.2 summarize the efficiency assumptions and energy savings results for technologies that DOE/BT will further analyze. The key assumptions and results were summarized for 12 cooling technologies in Table A-15.1 and for boilers and a high-capacity instantaneous water heater in Table A-15.2. Cumulative savings, shown in the last column in both tables, were based on the savings from the effective date of the standards through 2030.

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 9-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $9).

Distribution Transformers

Distribution transformers convert high-voltage electricity from distribution centers to lower-voltage electricity for use at the household level. During this conversion process, a small fraction of heat is lost. Rules are being written to reduce the amount of heat loss during this conversion process.

Savings estimates for a distribution transformer standard were based on a study conducted by Geller and Nadel.[7] The study assumed the following:

- Savings of 80 watts per unit
- See Table A-15.3.
- 20% sales complying with the new level without the standard
- 8,760 annual operating hours per unit
- 13-year life of equipment.

The savings estimate of 80 watts per unit installed was multiplied by the estimated hours of operation and then by the forecasted number of units installed.

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[m] The level is based on a judgmental assessment and should not be construed as representing an official DOE position regarding the potential level at this standard. Analytical work is currently underway to assess the most appropriate level of the standard if a decision to promulgate a new rule is made.

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

Project/Technology Consumer Costs (PNNL Estimate):

- Incremental investment costs were developed assuming a 10-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $10).

Table A-15.1. Key Assumptions and Results for Cooling Products

Equipment Category	Efficiency (SEER and EER)*			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
3-Phase Single Package, Air Source Air Conditioning, <65 kBtu/h	9.7	12.0	2005	4.6	21.0	26.5	396.0
3-Phase Single Package, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	1.2	3.1	3.4	60.2
3-Phase Split, Air Source Air Conditioning, <65 kBtu/h	9.7	11.0	2005	0.9	4.1	5.2	78.1
3-Phase Split, Air Source Heat Pump, <65 kBtu/h	9.7	12.0	2005	9.1	24.0	26.5	463.0
Central, Water Source Heat Pump, >17 and <65 kBtu/h	9.3	12.5	2008	1.5	7.1	11.1	146.9
Central, Air Source Air Conditioning, >=65 and <135 kBtu/h	8.9	11.0	2008	5.5	25.0	31.6	471.6
Central, Air Source Air Conditioning, >=135 and <240 kBtu/h	8.5	11.0	2008	5.4	24.6	31.0	463.1
Packaged Terminal Air Conditioning, 7-10 kBtu/h	8.6	10.8	2008	0.4	1.8	2.2	33.3
Packaged Terminal Air Conditioning, 10-13 kBtu/h	8.1	10.2	2008	0.6	2.6	3.3	49.5

* SEER = seasonal energy efficiency ratio; EER = energy efficiency ratio.

Residential Gas Furnaces

Rules related to the efficiency of residential gas furnaces are being written with the anticipated adoption date of 2008. PNNL estimated savings for residential gas furnaces using NEMS-PNNL and the following assumptions:

- Proposed residential gas furnace efficiency of 82% annual fuel utilization efficiency
- Introduction date of 2008
- Cost of $1400.

Non-Energy Benefits:[(1)]

- Reduced CO_2 and SO_X emissions

- Reduced water consumption from plumbing equipment
- Increased life of equipment operating at cooler temperatures
- Reduced first costs that transform new technologies into commodities.

Table A-15.2. Key Assumptions and Results for Boilers and a High-Capacity Instantaneous Water Heater

Equipment Category	Efficiency (SEER and EER)			Energy Savings by Year (TBtu)			
	EPAct	New Std	Eff. Date	2010	2020	2030	Cum.
Pkg'd Boilers, Gas, 400 kBtu/h, Hot Water	75%	78%	2008	0.2	0.9	1.7	19.7
Pkg'd Boilers, Gas, 800 kBtu/h, Hot Water	75%	78%	2008	0.4	2.0	3.7	43.0
Pkg'd Boilers, Gas, 1500 kBtu/h, Hot Water	75%	78%	2008	0.1	0.7	1.2	14.2
Pkg'd Boilers, Gas, 3000 kBtu/h, HW	75%	80%	2008	0.2	0.7	1.3	15.2
Pkg'd Boilers, Gas, 400 kBtu/h, Steam	72%	76%	2008	0.1	0.6	1.1	12.6
Pkg'd Boilers, Gas, 800 kBtu/h, Steam	72%	76%	2008	0.4	1.6	3.0	34.5
Pkg'd Boilers, Gas, 1500 kBtu/h, Steam	72%	79%	2008	0.3	1.2	2.3	26.7
Pkg'd Boilers, Gas, 3000 kBtu/h, Steam	72%	80%	2008	0.2	0.9	1.7	19.2
Instantaneous Water Heaters, 1000 kBtu/h	80%	83%	2008	1.0	4.4	5.6	83.3

Table A-15.3. Distribution Transformer Market Penetration

Year	Transformer Sales Forecast
2004	1,592,533
2005	1,623,086
2006	1,654,225
2007	1,685,962
2008	1,718,307
2009	1,751,273
2010	1,784,871
2011	1,819,115
2012	1,854,015
2013	1,889,584
2014	1,925,836
2015	1,962,784
2016	2,000,440
2017	2,038,819
2018	2,077,934
2019	2,117,799
2020	2,158,429
2021	2,199,839
2022	2,242,044
2023	2,285,057
2024	2,328,057
2025	2,373,577
2026	2,419,114
2027	2,465,525
2028	2,512,827
2029	2,561,036
2030	2,610,170

Sources:

(1) FY 2002 Budget Request - *Data Bucket Report for the Lighting and Appliance Standards Program* (internal BTS document).
(2) National Appliance Energy Conservation Act of 1987, Public Law 100-12.
(3) Energy Policy Act of 1992, Public Law 102-486.
(4) Somasundaran, S. et al. 2000. *Screening Analysis of EPAct-Covered Commercial HVAC and Water Heating Equipment*. PNNL-13232, Pacific Northwest National Laboratory, Richland, Washington..
(5) ASHRAE 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(6) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

A.15 Equipment Standards and Analysis

Equipment Standards and Analysis

(7) Geller, H., and S. Nadel. 1992. "Consensus National Efficiency Standards for Lamps, Motors, Showerheads and Faucets, and Commercial HVAC Equipment." In *American Council for an Energy Efficient Economy Proceedings*, pp. 6.71-6.82.

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Appendix B – Weatherization and Intergovernmental Program

This appendix describes the results of the forecasted energy savings, consumer cost savings, and carbon benefits for each of the 12 WIP projects (for 2004, 2005, 2010, and 2020). Tables show forecasted benefits up to the year 2030 for all projects and decision units. The projects for WIP are also summarized in this appendix.

B.1 Energy Savings Analysis by Decision Unit

Decision unit benefits are reported annually. The energy savings estimates for 2010 represent energy saved in 2010 only; these are not cumulative benefits estimates. However, the energy savings in 2010 are a function of all project activities from FY 2004 on, so the number of affected buildings is a cumulative value. For example, for the ENERGY STAR CFLs, the energy saved in 2010 is the energy saved in 2010 only, from all buildings that have had such lights installed any time between FY 2004 and FY 2010.

Table B-1.1 summarizes the primary energy savings, the carbon equivalent reductions, and the consumer cost savings for the three WIP decision units.

Table B-1.1. Summary of Benefits: Analyses of WIP Projects

Decision Unit	FY 2004 Budget Request (Million $)	2004	2005	2010	2020
Primary Energy Savings (TBtu/Yr)					
Weatherization Assistance Project	288	8.6	16.9	57.6	122.5
State Energy Project	39	4.0	7.8	24.7	48.7
Gateway Deployment	18	39.2	73.4	271.6	975.6
Totals		51.8	98.2	353.9	1146.7
Carbon Equivalent Emission Reductions (MMTCE/Yr)					
Weatherization Assistance Project	288	0.1	0.3	1.0	2.0
State Energy Project	39	0.1	0.1	0.5	0.9
Gateway Deployment	18	0.7	1.3	5.3	18.5
Totals		0.9	1.7	6.8	21.4
Consumer Cost Savings (Million $/yr)					
Weatherization Assistance Project	288	60.0	117.0	411.0	917.0
State Energy Project	39	25.0	48.0	158.0	352.0
Gateway Deployment	18	259.0	479.0	2031.0	8611.0
Totals		344.0	643.0	2600.0	9880.0

Total primary energy savings for all WIP projects are estimated to reach 0.4 QBtu by year 2010 and 1.1 QBtu by year 2020. Figure B-1.1 charts annual energy savings for all WIP projects for the years FY 2004 to FY 2020. In the short-term, roughly half of the savings are generated in the residential sector and half in the commercial sector; however, in later years, relatively more energy savings (roughly two-thirds) are estimated to come from the residential sector.

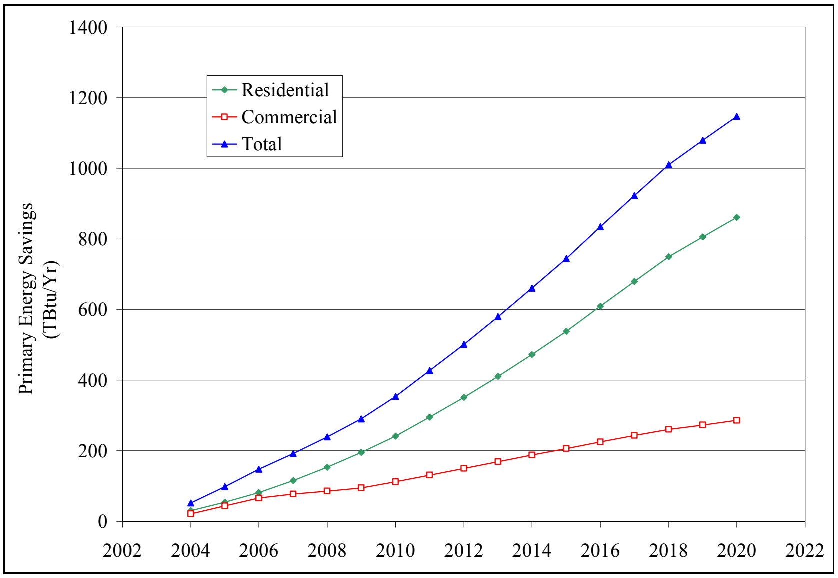

Figure B-1.1. WIP Primary Energy Savings by Sector through FY 2020

Figure B-1.2 compares the BT and WIP primary energy savings projections with building energy consumption forecasts from the *Annual Energy Outlook 2002*. The FY 2004 estimates include only savings for projects that are included in the FY 2004 WIP funding request. Some activities funded in previous years may contribute to total WIP future energy savings but are *not* in the FY 2004 request. For example, a project that supports a rulemaking that is completed in FY 2003 would not be included in the FY 2004 request; however, this project would produce energy savings in future years.

Figure B-1.2 shows savings for FY 2004 projects as well as projects that have been retired since FY 2000 but have future energy savings. The projections of WIP and BT project savings are charted relative to the building energy consumption forecasts generated by *Annual Energy Outlook 2002*. Figure B-1.2 shows that if the forecasted savings generated by WIP and BT projects are subtracted from forecasted total building energy use, total primary building energy use remains relatively flat through 2020.

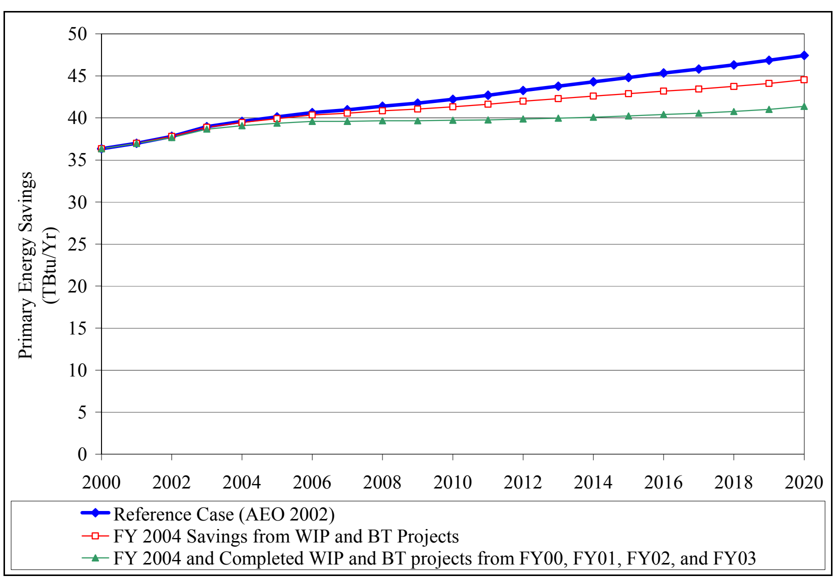

Figure B-1.2. Building Energy Consumption with and without BT/WIP Savings

Of all WIP energy savings (in year 2020), projects included in the Gateway Deployment decision unit generate 85% of the total savings (see Figure B-1.3). This decision unit includes information/education (e.g., Information Outreach), training (e.g., Building Codes Training), and market transformation (e.g., ENERGY STAR) projects. Gateway Deployment makes up ~5% of the overall WIP project FY 2004 budget. Weatherization Assistance makes up ~11% of the total savings while accounting for ~83% of the total budget request. The State Energy project decision unit makes up ~4% of the overall savings and accounts for 11% of the overall budget.

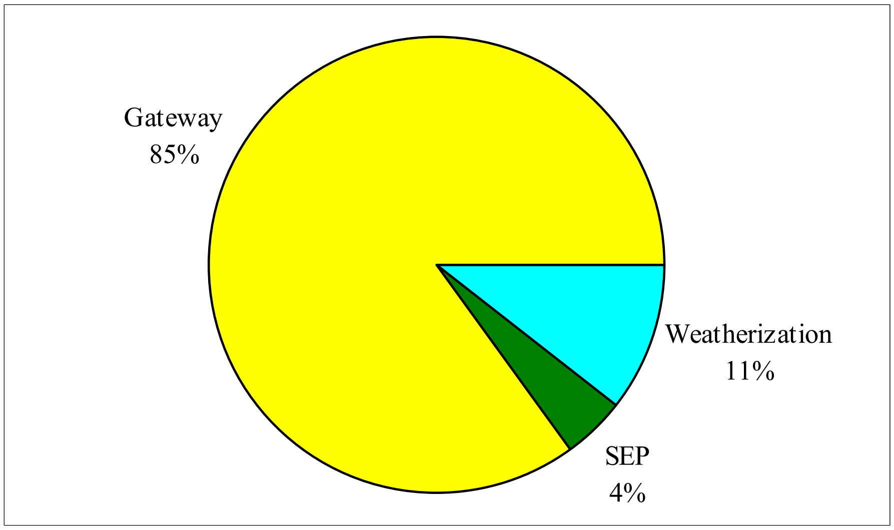

Figure B-1.3. WIP Primary Energy Savings by Decision Unit (for 2020)

In terms of energy savings per budget dollar, the Building Codes Training and Assistance project and ENERGY STAR have relatively high ratios of savings to budget dollar. The Building Energy Codes project benefits from having high penetration rates because the building codes upon which these estimates are based become regulatory mandates when adopted by states. ENERGY STAR focuses on market transformation through labeling and requires relatively few dollars to implement compared with projects that provide R&D or technical assistance. Projects such as Weatherization and State Energy tend to have relatively low ratios of savings to budget dollar because these projects provide grants and assistance directly to states and households. Figure B-1.4 charts the FY 2004 final budget request and the energy savings of each decision unit.

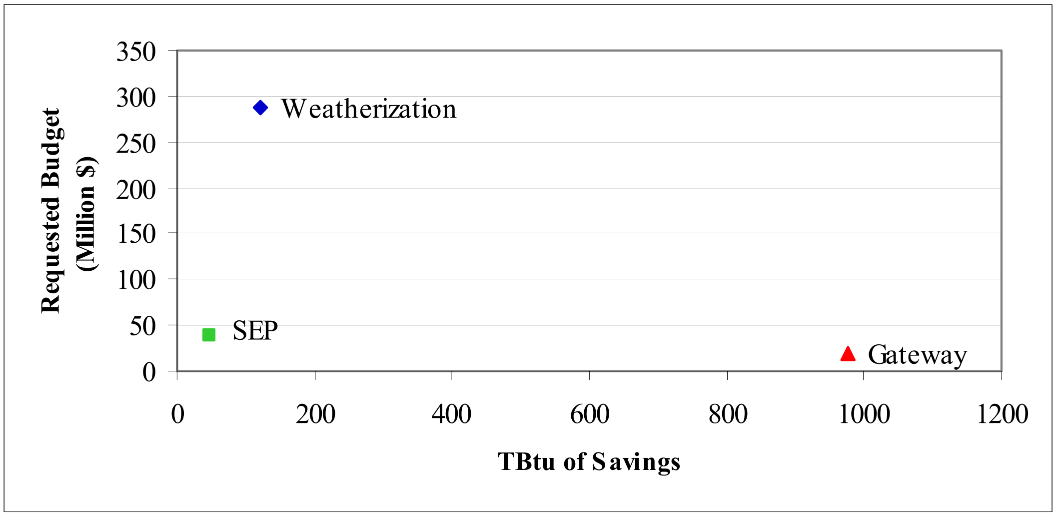

Figure B-1.4. Budget and Energy Savings Scatter Plot for WIP Decision Unit [a]

B.2 FY 2004 GPRA Metrics for WIP Based on FY 2004 WIP Budget Request

This section summarizes the GPRA metrics benefits estimates produced for WIP and submitted to PBFA as part of EERE's FY 2004 GPRA metrics effort. These estimates were produced in conjunction with the draft WIP FY 2004 budget request (dated February 3, 2003) and represent the expected benefits from project activities funded under the FY 2004 budget request. Benefits resulting from funding in years before FY 2004 are not included. Benefits accruing from future funding are included in the estimates.

B.2.1 Scope of Analysis

The benefits estimates are developed based on a series of assumptions developed project-by-project and documented in sections B.3 through B.8. These input assumptions are critical to the analysis and are developed through an iterative process with the Project Managers. It should be noted that because WIP projects are in different stages of maturity, there are varying degrees of corroborative studies available on which project information can be substantiated. Additionally, newer projects may not have estimates of future costs well-coordinated with performance estimates. For example, research projects would be expected to have more tenuous estimates of price and performance characteristics of potential products than deployment-related projects that feature products closer to market adoption. PNNL recognizes the varying levels of maturity and distance from market across projects and that the cost and performance characteristics improve as projects mature or as they near commercialization.

[a] Benefits estimates for both the State Energy Project and Weatherization Assistance include those resulting from activities using non-DOE (leveraged) funding. For FY 2004, an additional $155 million is assumed to be leveraged for SEP activities, and an additional $300 million is assumed to be leveraged for use in weatherization activities. See sections B.3 and B.4 for further details.

B.2.2 Comparison of FY 2003 GPRA Metrics with FY 2004 GPRA Metrics[b]

Energy savings estimates are reported to PBFA at a decision unit level; however, this section explains changes that arise at the individual project/technology level. While estimates at the project level are not reported to PBFA as part of the GPRA metrics, they provide a useful planning tool for WIP and variations should be understood.

Overall, the estimated energy savings from WIP projects through 2020 are lower in the early years than those associated with the FY 2003 request. The FY 2003 estimate of 0.46 QBtu in 2010 has fallen to 0.35 QBtu in the FY 2004 estimate. By 2020, the FY 2004 estimates have risen so that the FY 2004 estimate of primary savings in 2020 is slightly higher, increasing from 1.09 QBtu in the FY 2003 estimate to 1.14 QBtu.

The discussion has been divided into five categories relative to primary energy savings in the year 2020. Any other projects not mentioned did not result in any change in out-year primary energy savings estimates.

1. Projects characterized in FY 2003 but not in FY 2004
2. Projects that have not changed significantly between FY 2003 and FY 2004
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004
4. Projects that have changed more than 50% between FY 2003 and FY 2004
5. Projects characterized in FY 2004 but not in FY 2003.

Projects that fall into the first category have been completed or terminated and are not in the FY 2004 request. Projects that fall into the fifth category were not characterized in the FY 2003 metrics because either they were new to the FY 2004 request or not enough information was available about them in FY 2003 to characterize them.

In general, projects are included in GPRA based on whether they are a line item in the initial budget request with a specific funding allocation. Occasionally, projects do not appear as a line item in the initial funding request but do appear in the final request. These projects are characterized within GPRA metrics only if enough information is available to characterize the project in a short period of time. For projects covering a suite of technologies, the technologies characterized are based on discussions with the project manager. The suites of technologies may change from year to year as the project manager changes focus. The suite of technologies is meant to represent the project not to capture all funded activities. The impact of these categories of projects is discussed below and shown in Table B-2.1:

- Projects characterized in FY 2003 but not in FY 2004 – No WIP projects or activities were assumed to be completed or terminated between FY 2003 and FY 2004.

- Projects that have not changed significantly between FY 2003 and FY 2004 – The modeling methods or characterizations for four WIP projects or technologies did not change significantly between FY 2003 and FY 2004:
  - State Energy Project
  - Rebuild America
  - Training and Technical Assistance for Codes

[b] FY 2003 GPRA Metrics based on BESET Run 4N; FY 2004 GPRA Metrics based on BESET Run 5.

– Energy Star: CFLs.

- Projects that have changed 25% to 50% between FY 2003 and FY 2004 – The Information Outreach project decreased ~28 TBtu in 2020 because of a significant budget request decrease.

- Projects that have changed more than 50% between FY 2003 and FY 2004 – No WIP projects fell into this category.

- Projects characterized in FY 2004 but not in FY 2003 – No projects fell into this category.

Table B-2.1. Impact of WIP Project Changes

Changes by Category	Year 2020 (TBtu)
FY 2003 Estimate	1,091
Less	
1. Projects characterized in FY 2003 but not in FY 2004	0
Plus	
2. Projects that have not changed significantly between FY 2003 and FY 2004	83
3. Projects that have changed 25% to 50% between FY 2003 and FY 2004	- 28
4. Projects that have changed more than 50% between FY 2003 and FY 2004	0
5. Projects characterized in FY 2004 but not in FY 2003	0
Equals	
FY 2004 Estimate	1,147

B.2.3 FY 2004 GPRA Metrics – Detailed Tables

Tables B-2.2 through B-2.19 are included here to show forecasted benefits up to the year 2030 for all projects and decision units. The benefit estimates available include:

- Energy Savings Benefits Tables (TBtu per year)
  - Total Primary Energy Savings
  - Total Site Energy Savings
  - Primary Electricity Energy Savings
  - Primary Non-Electric Energy Savings
  - Site Electricity Energy Savings
  - Site Natural Gas Energy Savings
  - Site Fuel Oil Energy Savings

- Environmental Benefits Tables (million metric tons per year)
  - Carbon Equivalent Emissions Reductions
  - SO_2 Emissions Reductions
  - NO_X Emissions Reductions
  - CO Emissions Reductions

- PM Emissions Reductions
- VOC Emissions Reductions

- Financial Benefits Tables (million $ per year)
  - Consumer Cost Savings
  - Non-Energy Cost Savings
  - Incremental Private Investment

- Employment and Income Impacts Tables (from ImBuild)
  - Employment Impacts, Savings Only (thousand jobs per year)
  - Income Impacts, Savings Only (million $ per year).

Project benefits are reported annually in the tables. The energy savings estimate for 2010 represents energy saved in 2010 only. These are not cumulative benefits estimates. However, the energy saved in 2010 is a function of all project activities from FY 2004 on, so that the number of affected buildings is a cumulative value. For example, the energy saved in 2010 from the CFLs (within Energy Star) is the energy saved in 2010 only, from all buildings that have had such lights installed any time between 2004 and 2010.

Reductions in emissions from WIP projects are calculated from GPRA metrics estimates of energy savings by fuel type, multiplied by emissions coefficients provided by PBFA for the GPRA metrics.

The consumer cost savings estimates are calculated from GPRA metrics estimates of energy savings by sector and fuel type, multiplied by energy price forecasts provided by PBFA for the GPRA metrics.

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.2. Primary Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**8.6**	**16.9**	**25.1**	**33.5**	**41.6**	**57.6**	**98.1**	**122.5**	**123.5**	**123.5**
Weatherization Assistance	8.6	16.9	25.1	33.5	41.6	57.6	98.1	122.5	123.5	123.5
2 State Energy Project	**4.0**	**7.8**	**11.5**	**15.2**	**18.6**	**24.7**	**40.1**	**48.7**	**48.7**	**48.7**
State Energy Project	4.0	7.8	11.5	15.2	18.6	24.7	40.1	48.7	48.7	48.7
3 Gateway Deployment	**39.2**	**73.4**	**110.8**	**143.5**	**178.8**	**271.6**	**606.5**	**975.6**	**1,238.7**	**1,413.0**
Rebuild America	1.6	3.0	5.1	8.2	10.8	16.7	21.8	20.8	20.9	21.1
Energy Efficiency Information Outreach	14.6	29.0	42.3	42.2	41.1	39.2	37.1	36.0	36.0	36.0
Building Codes Training and Assistance	4.7	11.1	18.4	27.9	38.0	72.0	201.4	320.7	427.4	525.9
Energy Star: Clothes Washers	13.5	17.9	22.0	26.5	30.5	37.8	51.3	63.9	78.6	94.6
Energy Star: Refrigerators	0.4	1.0	1.8	3.0	4.0	5.8	10.0	13.0	17.0	21.5
Energy Star: Electric Water Heaters	0.1	0.5	1.1	2.3	4.6	12.9	32.8	55.4	83.2	115.1
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.3	0.6	0.8	1.0	1.2	1.5	2.3	3.1	4.1	5.3
Energy Star: CFLs	3.7	10.0	18.5	31.1	46.8	82.9	243.0	448.6	549.2	562.3
Energy Star: Dishwashers	0.2	0.4	0.7	0.8	1.0	1.4	2.4	3.5	4.9	6.5
Weatherization and Intergovernmental Activities Total	**51.8**	**98.2**	**147.4**	**192.2**	**238.9**	**353.9**	**744.7**	**1,146.7**	**1,410.9**	**1,585.1**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
MDB: K:\METRICS\FY2004\BESET Inputs\Run 5\FY 2004 Run 5.mdb

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.3. Site Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**7.2**	**14.1**	**21.2**	**28.3**	**35.4**	**49.9**	**86.4**	**108.9**	**109.8**	**109.8**
Weatherization Assistance	7.2	14.1	21.2	28.3	35.4	49.9	86.4	108.9	109.8	109.8
2 State Energy Project	**2.1**	**4.2**	**6.4**	**8.5**	**10.6**	**14.8**	**25.4**	**31.8**	**31.8**	**31.8**
State Energy Project	2.1	4.2	6.4	8.5	10.6	14.8	25.4	31.8	31.8	31.8
3 Gateway Deployment	**20.2**	**36.4**	**55.0**	**68.8**	**85.8**	**133.0**	**299.9**	**488.4**	**622.5**	**720.0**
Rebuild America	1.1	1.9	3.4	5.4	7.3	11.6	15.8	15.2	15.2	15.2
Energy Efficiency Information Outreach	7.9	15.8	23.6	23.6	23.6	23.6	23.6	23.6	23.6	23.6
Building Codes Training and Assistance	1.7	3.8	6.4	9.8	14.4	31.5	101.0	169.3	228.8	284.6
Energy Star: Clothes Washers	8.1	10.8	13.7	16.6	19.5	25.3	36.0	46.2	57.1	68.8
Energy Star: Refrigerators	0.1	0.3	0.6	1.0	1.4	2.2	4.1	5.6	7.3	9.3
Energy Star: Electric Water Heaters	0.0	0.2	0.4	0.8	1.6	4.9	13.6	24.0	36.0	49.8
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.1	0.2	0.3	0.3	0.4	0.6	1.0	1.4	1.8	2.3
Energy Star: CFLs	1.2	3.2	6.2	10.5	16.4	31.3	99.6	191.1	233.2	238.7
Energy Star: Dishwashers	0.1	0.1	0.2	0.3	0.4	0.5	1.0	1.5	2.1	2.8
Weatherization and Intergovernmental Activities Total	**29.5**	**54.8**	**82.5**	**105.5**	**131.7**	**197.7**	**411.8**	**629.1**	**764.0**	**861.5**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.4. Primary Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**2.2**	**4.2**	**6.0**	**8.0**	**9.6**	**12.5**	**19.9**	**23.9**	**24.1**	**24.1**
Weatherization Assistance	2.2	4.2	6.0	8.0	9.6	12.5	19.9	23.9	24.1	24.1
2 State Energy Project	**2.7**	**5.3**	**7.7**	**10.2**	**12.3**	**15.9**	**25.0**	**29.9**	**29.9**	**29.9**
State Energy Project	2.7	5.3	7.7	10.2	12.3	15.9	25.0	29.9	29.9	29.9
3 Gateway Deployment	**27.8**	**54.6**	**84.2**	**112.8**	**143.2**	**223.1**	**522.5**	**859.0**	**1,086.6**	**1,222.0**
Rebuild America	0.9	1.6	2.6	4.2	5.4	8.1	10.3	9.9	10.1	10.4
Energy Efficiency Information Outreach	9.9	19.5	28.1	28.0	27.0	25.0	22.9	21.8	21.8	21.8
Building Codes Training and Assistance	4.3	10.7	18.2	27.4	36.3	65.2	171.2	267.0	350.2	425.5
Energy Star: Clothes Washers	8.0	10.4	12.5	15.0	16.9	20.2	26.1	31.1	37.9	45.5
Energy Star: Refrigerators	0.4	1.0	1.8	3.0	4.0	5.8	10.0	13.0	17.0	21.5
Energy Star: Electric Water Heaters	0.1	0.5	1.1	2.3	4.6	12.9	32.8	55.4	83.2	115.1
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.3	0.6	0.8	1.0	1.2	1.5	2.3	3.1	4.1	5.3
Energy Star: CFLs	3.7	10.0	18.5	31.1	46.8	83.1	244.5	454.1	557.3	570.5
Energy Star: Dishwashers	0.2	0.4	0.7	0.8	1.0	1.4	2.4	3.5	4.9	6.5
Weatherization and Intergovernmental Activities Total	**32.7**	**64.0**	**97.9**	**131.0**	**165.1**	**251.6**	**567.4**	**912.8**	**1,140.6**	**1,276.0**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.5. Primary Non-Electric Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**6.5**	**12.8**	**19.2**	**25.6**	**32.0**	**45.1**	**78.2**	**98.6**	**99.4**	**99.4**
Weatherization Assistance	6.5	12.8	19.2	25.6	32.0	45.1	78.2	98.6	99.4	99.4
2 State Energy Project	**1.3**	**2.5**	**3.8**	**5.0**	**6.3**	**8.8**	**15.1**	**18.8**	**18.8**	**18.8**
State Energy Project	1.3	2.5	3.8	5.0	6.3	8.8	15.1	18.8	18.8	18.8
3 Gateway Deployment	**11.4**	**18.8**	**26.6**	**30.6**	**35.5**	**48.5**	**84.0**	**116.6**	**152.1**	**190.9**
Rebuild America	0.8	1.4	2.5	4.0	5.4	8.6	11.5	11.0	10.8	10.7
Energy Efficiency Information Outreach	4.7	9.5	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
Building Codes Training and Assistance	0.3	0.4	0.2	0.5	1.7	6.8	30.3	53.7	77.2	100.4
Energy Star: Clothes Washers	5.5	7.5	9.5	11.5	13.6	17.6	25.2	32.8	40.7	49.1
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	-0.1	-1.5	-5.5	-8.1	-8.2
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**19.1**	**34.1**	**49.5**	**61.2**	**73.8**	**102.4**	**177.3**	**234.0**	**270.3**	**309.1**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.6. Site Electricity Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.7**	**1.3**	**2.0**	**2.7**	**3.4**	**4.7**	**8.2**	**10.4**	**10.4**	**10.4**
Weatherization Assistance	0.7	1.3	2.0	2.7	3.4	4.7	8.2	10.4	10.4	10.4
2 State Energy Project	**0.9**	**1.7**	**2.6**	**3.4**	**4.3**	**6.0**	**10.3**	**12.9**	**12.9**	**12.9**
State Energy Project	0.9	1.7	2.6	3.4	4.3	6.0	10.3	12.9	12.9	12.9
3 Gateway Deployment	**8.8**	**17.6**	**28.4**	**38.1**	**50.3**	**84.5**	**215.9**	**371.9**	**470.4**	**529.0**
Rebuild America	0.3	0.5	0.9	1.4	1.9	3.1	4.2	4.3	4.4	4.5
Energy Efficiency Information Outreach	3.2	6.3	9.5	9.5	9.5	9.5	9.5	9.5	9.5	9.5
Building Codes Training and Assistance	1.4	3.4	6.1	9.3	12.7	24.7	70.7	115.6	151.6	184.2
Energy Star: Clothes Washers	2.6	3.4	4.2	5.1	5.9	7.7	10.8	13.5	16.4	19.7
Energy Star: Refrigerators	0.1	0.3	0.6	1.0	1.4	2.2	4.1	5.6	7.3	9.3
Energy Star: Electric Water Heaters	0.0	0.2	0.4	0.8	1.6	4.9	13.6	24.0	36.0	49.8
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.1	0.2	0.3	0.3	0.4	0.6	1.0	1.4	1.8	2.3
Energy Star: CFLs	1.2	3.2	6.2	10.5	16.4	31.5	101.0	196.6	241.3	247.0
Energy Star: Dishwashers	0.1	0.1	0.2	0.3	0.4	0.5	1.0	1.5	2.1	2.8
Weatherization and Intergovernmental Activities Total	**10.4**	**20.7**	**33.0**	**44.3**	**57.9**	**95.3**	**234.4**	**395.1**	**493.8**	**552.4**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.7. Site Natural Gas Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**4.6**	**9.0**	**13.5**	**18.0**	**22.6**	**31.8**	**55.2**	**69.5**	**70.1**	**70.1**
Weatherization Assistance	4.6	9.0	13.5	18.0	22.6	31.8	55.2	69.5	70.1	70.1
2 State Energy Project	**0.3**	**0.5**	**0.8**	**1.0**	**1.3**	**1.8**	**3.0**	**3.8**	**3.8**	**3.8**
State Energy Project	0.3	0.5	0.8	1.0	1.3	1.8	3.0	3.8	3.8	3.8
3 Gateway Deployment	**10.0**	**16.6**	**23.5**	**26.9**	**31.1**	**42.3**	**73.5**	**102.6**	**134.7**	**170.2**
Rebuild America	0.7	1.3	2.3	3.7	5.0	8.0	10.7	10.2	10.1	10.1
Energy Efficiency Information Outreach	4.3	8.7	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
Building Codes Training and Assistance	0.2	0.2	-0.2	-0.1	0.7	4.8	24.9	45.2	65.8	86.2
Energy Star: Clothes Washers	4.7	6.4	8.2	9.9	11.7	15.3	22.1	29.0	36.3	44.2
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.1	0.2	0.4	0.7	1.5	4.3	10.5	17.3	24.7
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	-0.1	-1.4	-5.3	-7.9	-8.0
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**14.8**	**26.2**	**37.8**	**46.0**	**54.9**	**75.9**	**131.7**	**175.8**	**208.5**	**244.0**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.8. Site Fuel Oil Energy Savings (TBtu/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**1.9**	**3.8**	**5.7**	**7.6**	**9.5**	**13.3**	**23.1**	**29.1**	**29.3**	**29.3**
Weatherization Assistance	1.9	3.8	5.7	7.6	9.5	13.3	23.1	29.1	29.3	29.3
2 State Energy Project	**1.0**	**2.0**	**3.0**	**4.0**	**5.0**	**7.0**	**12.0**	**15.1**	**15.1**	**15.1**
State Energy Project	1.0	2.0	3.0	4.0	5.0	7.0	12.0	15.1	15.1	15.1
3 Gateway Deployment	**1.4**	**2.2**	**3.1**	**3.7**	**4.4**	**6.1**	**10.5**	**14.0**	**17.4**	**20.8**
Rebuild America	0.1	0.1	0.2	0.3	0.4	0.6	0.8	0.7	0.7	0.7
Energy Efficiency Information Outreach	0.4	0.8	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
Building Codes Training and Assistance	0.1	0.2	0.4	0.6	1.0	2.0	5.4	8.5	11.4	14.2
Energy Star: Clothes Washers	0.8	1.1	1.3	1.6	1.8	2.3	3.1	3.8	4.4	5.0
Energy Star: Refrigerators	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Electric Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: Room Air Conditioners	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Energy Star: CFLs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	-0.2	-0.2	-0.2
Energy Star: Dishwashers	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Weatherization and Intergovernmental Activities Total	**4.3**	**8.0**	**11.8**	**15.3**	**18.9**	**26.5**	**45.6**	**58.2**	**61.8**	**65.1**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.9. Carbon Equivalent Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.143**	**0.282**	**0.422**	**0.570**	**0.707**	**0.977**	**1.645**	**2.040**	**2.057**	**2.057**
Weatherization Assistance	0.143	0.282	0.422	0.570	0.707	0.977	1.645	2.040	2.057	2.057
2 State Energy Project	**0.073**	**0.147**	**0.219**	**0.300**	**0.367**	**0.490**	**0.779**	**0.933**	**0.933**	**0.933**
State Energy Project	0.073	0.147	0.219	0.300	0.367	0.490	0.779	0.933	0.933	0.933
3 Gateway Deployment	**0.673**	**1.307**	**2.031**	**2.746**	**3.451**	**5.305**	**11.662**	**18.467**	**23.426**	**26.638**
Rebuild America	0.027	0.051	0.088	0.144	0.190	0.292	0.375	0.354	0.355	0.360
Energy Efficiency Information Outreach	0.249	0.507	0.755	0.777	0.759	0.722	0.666	0.636	0.636	0.636
Building Codes Training and Assistance	0.084	0.207	0.358	0.566	0.768	1.445	3.871	6.014	7.987	9.801
Energy Star: Clothes Washers	0.228	0.309	0.386	0.478	0.550	0.681	0.899	1.097	1.348	1.618
Energy Star: Refrigerators	0.007	0.018	0.035	0.061	0.081	0.119	0.199	0.253	0.330	0.418
Energy Star: Electric Water Heaters	0.002	0.009	0.021	0.047	0.095	0.265	0.653	1.077	1.619	2.239
Energy Star: Gas Water Heaters	0.000	0.001	0.003	0.006	0.010	0.021	0.061	0.151	0.249	0.356
Energy Star: Room Air Conditioners	0.006	0.010	0.016	0.020	0.024	0.030	0.047	0.061	0.080	0.103
Energy Star: CFLs	0.067	0.187	0.357	0.630	0.952	1.701	4.843	8.756	10.726	10.981
Energy Star: Dishwashers	0.003	0.007	0.013	0.017	0.021	0.029	0.048	0.068	0.096	0.127
Weatherization and Intergovernmental Activities Total	**0.889**	**1.736**	**2.672**	**3.615**	**4.525**	**6.773**	**14.086**	**21.440**	**26.416**	**29.628**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.10. SO_2 Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.001**	**0.003**	**0.005**	**0.006**	**0.008**	**0.011**	**0.018**	**0.022**	**0.022**	**0.022**
Weatherization Assistance	0.001	0.003	0.005	0.006	0.008	0.011	0.018	0.022	0.022	0.022
2 State Energy Project	**0.001**	**0.002**	**0.004**	**0.005**	**0.006**	**0.009**	**0.013**	**0.016**	**0.016**	**0.016**
State Energy Project	0.001	0.002	0.004	0.005	0.006	0.009	0.013	0.016	0.016	0.016
3 Gateway Deployment	**0.006**	**0.014**	**0.024**	**0.037**	**0.047**	**0.073**	**0.153**	**0.233**	**0.294**	**0.332**
Rebuild America	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.003	0.003	0.003
Energy Efficiency Information Outreach	0.002	0.005	0.008	0.009	0.009	0.008	0.007	0.006	0.006	0.006
Building Codes Training and Assistance	0.001	0.003	0.005	0.009	0.012	0.022	0.051	0.075	0.098	0.119
Energy Star: Clothes Washers	0.002	0.003	0.004	0.005	0.006	0.008	0.009	0.010	0.012	0.015
Energy Star: Refrigerators	0.000	0.000	0.000	0.001	0.001	0.002	0.003	0.003	0.004	0.006
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.001	0.001	0.004	0.009	0.015	0.022	0.030
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Star: CFLs	0.001	0.002	0.005	0.010	0.015	0.026	0.069	0.119	0.146	0.150
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.002
Weatherization and Intergovernmental Activities Total	**0.009**	**0.019**	**0.032**	**0.048**	**0.061**	**0.093**	**0.185**	**0.270**	**0.332**	**0.369**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.11. NO_X Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.008**	**0.013**	**0.016**	**0.016**	**0.016**
Weatherization Assistance	0.001	0.002	0.003	0.004	0.005	0.008	0.013	0.016	0.016	0.016
2 State Energy Project	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.004**	**0.006**	**0.008**	**0.008**	**0.008**
State Energy Project	0.001	0.001	0.002	0.003	0.003	0.004	0.006	0.008	0.008	0.008
3 Gateway Deployment	**0.005**	**0.011**	**0.017**	**0.024**	**0.030**	**0.047**	**0.102**	**0.161**	**0.204**	**0.231**
Rebuild America	0.000	0.000	0.001	0.001	0.002	0.002	0.003	0.003	0.003	0.003
Energy Efficiency Information Outreach	0.002	0.004	0.006	0.007	0.006	0.006	0.006	0.005	0.005	0.005
Building Codes Training and Assistance	0.001	0.002	0.003	0.005	0.007	0.013	0.034	0.052	0.069	0.084
Energy Star: Clothes Washers	0.002	0.003	0.003	0.004	0.005	0.006	0.007	0.009	0.011	0.013
Energy Star: Refrigerators	0.000	0.000	0.000	0.001	0.001	0.001	0.002	0.002	0.003	0.004
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.010	0.014	0.020
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Energy Star: CFLs	0.001	0.002	0.003	0.006	0.009	0.016	0.043	0.078	0.095	0.097
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Weatherization and Intergovernmental Activities Total	**0.007**	**0.014**	**0.022**	**0.031**	**0.039**	**0.059**	**0.121**	**0.184**	**0.227**	**0.255**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.12. CO Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.003**
Weatherization Assistance	0.000	0.000	0.001	0.001	0.001	0.001	0.002	0.003	0.003	0.003
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.001**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
3 Gateway Deployment	**0.001**	**0.002**	**0.002**	**0.003**	**0.004**	**0.006**	**0.013**	**0.021**	**0.027**	**0.031**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Efficiency Information Outreach	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Building Codes Training and Assistance	0.000	0.000	0.000	0.001	0.001	0.001	0.004	0.007	0.009	0.012
Energy Star: Clothes Washers	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.002	0.002
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.001	0.001	0.002	0.005	0.009	0.012	0.012
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.001**	**0.002**	**0.003**	**0.004**	**0.005**	**0.007**	**0.016**	**0.025**	**0.031**	**0.035**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.13. PM Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Weatherization Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Gateway Deployment	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.005**	**0.007**	**0.008**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Efficiency Information Outreach	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Codes Training and Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.002	0.003
Energy Star: Clothes Washers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.003	0.003	0.003
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.000**	**0.000**	**0.001**	**0.001**	**0.001**	**0.002**	**0.004**	**0.006**	**0.007**	**0.008**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.14. VOC Emissions Reductions (MMTons/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
Weatherization Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2 State Energy Project	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
State Energy Project	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3 Gateway Deployment	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**
Rebuild America	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Efficiency Information Outreach	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Building Codes Training and Assistance	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001
Energy Star: Clothes Washers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Refrigerators	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Electric Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Gas Water Heaters	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: Room Air Conditioners	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Energy Star: CFLs	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001
Energy Star: Dishwashers	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Weatherization and Intergovernmental Activities Total	**0.000**	**0.000**	**0.000**	**0.000**	**0.001**	**0.001**	**0.002**	**0.003**	**0.003**	**0.004**

Run Title: FY 2004 Run 5 **Scenario Last Executed:** 2/12/2003 1:41:24 PM
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WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.15. Consumer (Energy) Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$60**	**$117**	**$175**	**$233**	**$292**	**$411**	**$716**	**$917**	**$934**	**$944**
Weatherization Assistance	$60	$117	$175	$233	$292	$411	$716	$917	$934	$944
2 State Energy Project	**$25**	**$48**	**$70**	**$92**	**$114**	**$158**	**$275**	**$352**	**$359**	**$367**
State Energy Project	$25	$48	$70	$92	$114	$158	$275	$352	$359	$367
3 Gateway Deployment	**$259**	**$479**	**$743**	**$963**	**$1,247**	**$2,031**	**$5,013**	**$8,611**	**$11,018**	**$12,601**
Rebuild America	$11	$19	$33	$53	$71	$113	$155	$154	$157	$160
Energy Efficiency Information Outreach	$90	$175	$258	$253	$251	$247	$249	$255	$259	$263
Building Codes Training and Assistance	$31	$73	$124	$183	$257	$509	$1,531	$2,572	$3,461	$4,304
Energy Star: Clothes Washers	$94	$124	$156	$188	$221	$285	$404	$519	$641	$774
Energy Star: Refrigerators	$3	$7	$13	$22	$31	$48	$91	$125	$164	$209
Energy Star: Electric Water Heaters	$1	$4	$8	$17	$36	$107	$299	$531	$804	$1,119
Energy Star: Gas Water Heaters	$0	$0	$1	$3	$5	$10	$27	$69	$113	$162
Energy Star: Room Air Conditioners	$2	$4	$6	$7	$9	$12	$21	$30	$40	$52
Energy Star: CFLs	$26	$70	$137	$230	$359	$688	$2,214	$4,322	$5,331	$5,495
Energy Star: Dishwashers	$1	$3	$5	$6	$8	$12	$22	$34	$48	$63
Weatherization and Intergovernmental Activities Total	**$344**	**$643**	**$988**	**$1,288**	**$1,653**	**$2,600**	**$6,003**	**$9,880**	**$12,311**	**$13,912**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.16. Non-Energy Cost Savings (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$47**	**$45**	**$45**	**$45**	**$46**	**$46**	**$47**	**$47**	**$47**	**$47**
Weatherization Assistance	$47	$45	$45	$45	$46	$46	$47	$47	$47	$47
2 State Energy Project	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
State Energy Project	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3 Gateway Deployment	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**	**$0**
Rebuild America	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Efficiency Information Outreach	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Building Codes Training and Assistance	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Clothes Washers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Refrigerators	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Electric Water Heaters	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Gas Water Heaters	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Room Air Conditioners	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: CFLs	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Energy Star: Dishwashers	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Weatherization and Intergovernmental Activities Total	**$47**	**$45**	**$45**	**$45**	**$46**	**$46**	**$47**	**$47**	**$47**	**$47**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.17. Incremental Private Investment (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$536**	**$532**	**$539**	**$546**	**$554**	**$569**	**$578**	**$578**	**$578**	**$578**
Weatherization Assistance	$536	$532	$539	$546	$554	$569	$578	$578	$578	$578
2 State Energy Project	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**	**$164**
State Energy Project	$164	$164	$164	$164	$164	$164	$164	$164	$164	$164
3 Gateway Deployment	**$1,203**	**$1,605**	**$1,837**	**$2,086**	**$2,187**	**$2,790**	**$2,739**	**$2,201**	**$1,261**	**$449**
Rebuild America	$166	$163	$242	$317	$311	$392	$12	$9	$10	$9
Energy Efficiency Information Outreach	$180	$170	$167	$169	$166	$165	$164	$172	$174	$173
Building Codes Training and Assistance	$156	$207	$255	$297	$367	$791	$1,072	$997	$852	$913
Energy Star: Clothes Washers	$290	$336	$341	$345	$345	$351	$422	$443	$465	$488
Energy Star: Refrigerators	$80	$191	$272	$366	$369	$380	$409	$425	$441	$458
Energy Star: Electric Water Heaters	$9	$17	$31	$53	$90	$161	$149	$151	$153	$155
Energy Star: Gas Water Heaters	$0	$10	$17	$26	$37	$50	$103	$111	$120	$129
Energy Star: Room Air Conditioners	$239	$369	$371	$373	$366	$358	$423	$441	$458	$477
Energy Star: CFLs	$23	$29	$30	$29	$24	$26	-$144	-$683	-$1,553	$-2,503
Energy Star: Dishwashers	$59	$111	$110	$110	$111	$117	$128	$135	$142	$149
Weatherization and Intergovernmental Activities Total	**$1,903**	**$2,300**	**$2,539**	**$2,796**	**$2,905**	**$3,524**	**$3,481**	**$2,942**	**$2,003**	**$1,191**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.18. Employment Impacts, Savings Only (Thousand Jobs/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**0.6**	**0.8**	**1.2**	**1.6**	**2.0**	**2.9**	**5.0**	**6.3**	**6.5**	**6.6**
Weatherization Assistance	0.6	0.8	1.2	1.6	2.0	2.9	5.0	6.3	6.5	6.6
2 State Energy Project	**0.3**	**0.5**	**0.7**	**0.9**	**1.1**	**1.5**	**2.6**	**3.3**	**3.3**	**3.4**
State Energy Project	0.3	0.5	0.7	0.9	1.1	1.5	2.6	3.3	3.3	3.4
3 Gateway Deployment	**3.6**	**4.3**	**6.8**	**8.9**	**11.7**	**19.3**	**48.8**	**84.7**	**108.2**	**123.1**
Rebuild America	0.1	0.2	0.3	0.4	0.6	0.9	1.2	1.2	1.3	1.3
Energy Efficiency Information Outreach	1.3	1.5	2.3	2.2	2.2	2.1	2.2	2.2	2.2	2.3
Building Codes Training and Assistance	0.5	0.7	1.3	1.9	2.6	5.0	14.7	24.7	33.0	40.9
Energy Star: Clothes Washers	1.2	1.0	1.3	1.5	1.8	2.3	3.3	4.2	5.2	6.3
Energy Star: Refrigerators	0.0	0.1	0.1	0.2	0.3	0.5	0.9	1.3	1.7	2.2
Energy Star: Electric Water Heaters	0.0	0.0	0.1	0.2	0.4	1.1	3.1	5.5	8.3	11.5
Energy Star: Gas Water Heaters	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.8
Energy Star: Room Air Conditioners	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.3	0.4	0.5
Energy Star: CFLs	0.4	0.7	1.4	2.4	3.7	7.1	22.8	44.6	55.1	56.8
Energy Star: Dishwashers	0.0	0.0	0.1	0.1	0.1	0.1	0.2	0.4	0.5	0.7
Weatherization and Intergovernmental Activities Total	**4.5**	**5.6**	**8.7**	**11.4**	**14.8**	**23.6**	**56.3**	**94.3**	**118.0**	**133.0**

WIP GPRA Metrics Estimates

Based on FY 2004 Final Budget Request of 2/3/03

Table B-2.19. Income Impacts, Savings Only (Million $/Year)

	2004	2005	2006	2007	2008	2010	2015	2020	2025	2030
1 Weatherization Assistance	**$7**	**$6**	**$7**	**$8**	**$9**	**$11**	**$16**	**$19**	**$19**	**$20**
Weatherization Assistance	$7	$6	$7	$8	$9	$11	$16	$19	$19	$20
2 State Energy Project	**$5**	**$7**	**$11**	**$14**	**$17**	**$23**	**$41**	**$52**	**$53**	**$54**
State Energy Project	$5	$7	$11	$14	$17	$23	$41	$52	$53	$54
3 Gateway Deployment	**$37**	**$54**	**$87**	**$112**	**$145**	**$238**	**$611**	**$1,062**	**$1,353**	**$1,533**
Rebuild America	$1	$1	$2	$4	$5	$8	$11	$11	$12	$12
Energy Efficiency Information Outreach	$16	$23	$34	$33	$32	$32	$32	$32	$33	$33
Building Codes Training and Assistance	$6	$12	$20	$30	$40	$75	$215	$358	$473	$580
Energy Star: Clothes Washers	$9	$7	$9	$11	$12	$16	$23	$28	$34	$41
Energy Star: Refrigerators	$0	$1	$2	$3	$4	$6	$11	$16	$20	$26
Energy Star: Electric Water Heaters	$0	$0	$1	$2	$4	$13	$37	$66	$100	$140
Energy Star: Gas Water Heaters	$0	$0	$0	$0	$0	-$1	-$2	-$4	-$7	$-9
Energy Star: Room Air Conditioners	$0	$0	$1	$1	$1	$2	$3	$4	$5	$6
Energy Star: CFLs	$4	$9	$17	$29	$45	$86	$278	$546	$675	$696
Energy Star: Dishwashers	$0	$0	$1	$1	$1	$1	$3	$4	$6	$8
Weatherization and Intergovernmental Activities Total	**$49**	**$68**	**$105**	**$134**	**$171**	**$272**	**$667**	**$1,133**	**$1,425**	**$1,607**

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B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

Project Objective:[1]

The Weatherization Assistance Project provides cost-effective energy-efficiency services to low-income constituencies who otherwise could not afford the investment but who would benefit significantly from the cost savings of energy-efficiency technologies. The project focuses on households that spend a disproportionate amount of their income for energy, giving priority to households with elderly members, persons with disabilities, and children.

In 1999 the Weatherization network of state and local agencies adopted a new strategic vision called Weatherization *Plus.* The new strategy emphasizes a shift to the whole-house approach and includes electric baseload measures and advanced technologies. Within the new $2500 legislative cap on average expenditure per household, the mix of measures include those with enhanced impacts on greenhouse gas emissions and pollution reduction. Such measures include intensified building envelope and heating/cooling system measures, more health and safety measures (supporting other community goals), and more baseload uses such as water heating and lighting.

Long-Term Goal:[1]

The long-term goal of the Weatherization Assistance project is to achieve average energy savings of 31 million Btu in an additional 2.3 million existing low-income homes through 2011, consistent with the President's plan to increase Weatherization funding by $1.4 billion over FY 2000 baselines for the 10-year period. This investment will save participating households an estimated $4.2 billion in reduced energy bills over the period.

Market Segment:

Target Market

- Market Description: The market includes low-income homes and target measures include air sealing; caulking and weather stripping; furnace and boiler tuneup, repair, and replacement;

Weatherization Assistance Project

Project Type:
Envelope/Grant

Target Market:
Low-income residential housing in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per housing unit

Modeling Tool:
Spreadsheet

Project Manager:
Greg Reamy

Website:
http://www.eren.doe.gov/buildings/weatherization_assistance/

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FY2004 Benefits [c]

Primary Energy Savings (TBtu)

2004	2005	2010	2020
8.6	16.9	57.6	122.5

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.143	0.282	0.977	2.040

Consumer Cost Savings (million $)

2004	2005	2010	2020
60	117	411	917

[c] Benefits estimates for the Weatherization Assistance Project are the result of both DOE funding and an additional $300 million per year in leverage funds.

cooling system tuneup and repair; replacement of windows and doors; addition of storm windows and doors; insulation of building shells; and replacement of air conditioners, whole-house fans, evaporative coolers, screening, and window films.[2] Weatherization *Plus* expands this strategy to include water heating, refrigeration, lighting, and cooling.[1]

- Size of Market: ~29 million eligible low-income homes are included in the market.

Methodology:

For the GPRA metrics, this project was characterized based on an estimated level of savings per household, cost to weatherize each household, budget request, leveraged funds, and an assumed life expectancy of 15 years for weatherization measures. The basic assumptions were derived from a spreadsheet provided by the Weatherization project in September 2001.

Estimated Savings Per Household

Table B-3.1 shows the savings per household used for each region for the FY 2004 metrics.

Table B-3.1. Savings Per Household for the Weatherization Assistance Project

Region	Regular Household Savings (MMBtu/yr)	*Plus* Household Savings (MMBtu/yr)
South	22.25	24.23
Northeast	31.20	46.04
West	19.04	20.31
Midwest	31.20	49.21

The figures in the table were calculated based on the 1997 ORNL meta-evaluation report,[2] the ORNL *Meeting the Challenge* report,[3] and special tabulations from the 1997 "Residential Energy Consumption Survey."[4] Previous year's estimates were based on project resource allocations at levels reflecting a formula bias towards homes in colder climates in the Northeast and Midwest. The higher budget levels projected for FY 2002 and beyond are allocated under a formula that shifts a higher proportion of new revenues to the South and West, where saving rates are lower.

Of the units weatherized in FY 2004, ~40% were assumed by the Weatherization Project[3] to have the higher savings rates associated with Weatherization *Plus*. In the *Meeting The Challenge* report,[3] these savings rates were calculated on a regional basis and multiplied times the expected number of *Plus* households in each region.

To develop energy savings by building type, PNNL evaluated historical Weatherization project data in the 1997 ORNL report[2] concerning the types of households weatherized (see Table B-3.2).

Table B-3.2. Percent of Weatherized Households by Type

Household Type	% of Weatherized Households
Single Family	64.0%
Mobile Home	20.0%
Multi Family	16.0%

To develop energy savings by fuel type, PNNL also drew upon the historical primary fuel Weatherization project data in the 1997 ORNL report[2]. Because the GPRA metrics are reported for electricity, natural gas, and fuel oil, but not for LPG and kerosene, other fuels were allocated within those types based on similarities of emissions. Table B-3.3 shows the allocation approaches used.

Table B-3.3. Percent of Weatherized Households by Fuel Type

Primary Heating Fuel	% of Weatherized Households	Categorized As
Natural Gas	50.6	Natural Gas
Liquid Propane Gas	13.2	
Fuel Oil	16.0	Fuel Oil
Kerosene	3.2	
Other (includes wood and coal)	7.5	
Electricity	9.5	Electricity

Cost to Weatherize Each Household

PNNL employed the average household weatherization cost of $1,775; this estimate does not include training, technical assistance and administrative costs. Incremental investment beyond this for Weatherization *Plus* homes, estimated at an average of $1,400 by the Weatherization project, was assumed to be provided by other organizations, that is by leveraged funds. Table B-3.4 shows the estimated total costs by region for *Plus* homes.

Table B-3.4. Estimated Regional Costs for Weatherization *Plus* Homes

Region	Cost per *Plus* Household
South	$2861
Northeast	$3674
West	$1814
Midwest	$3429

B.3 Weatherization Assistance Project

Weatherization Assistance Project Decision Unit

DOE Funds Available
Because this is a grant project, this activity was assumed not to occur without DOE funding; therefore, we did not apply the NRC (acceleration-to-market) methodology. The FY 2004 Weatherization planning budget and forecast for FY 2004 to FY 2030 was used to calculate the number of households weatherized. The total funds allocated to training and technical assistance and administrative costs were estimated to total 20% during the period.

Leveraged Funding
Leveraging means that the project efforts are augmented by contributions from organizations other than DOE. These contributions can take the form of direct project-targeted funding or in-kind contributions such as staff, research-in-kind, facilities, or other nonmonetary resources. In any case, this definition only includes resources that can clearly be attributed to project activities and that are used to augment those activities.

Funding for activities conducted under the Weatherization Assistance project is leveraged; beyond DOE, funding sources include the Low-Income Home Energy Assistance Program at the U.S. Department of Health and Human Services, energy utilities, state agencies, private companies, and Petroleum Violation Escrow funds.

Rationale for Benefits Attribution to DOE
A series of arguments support the overall proposition that the entire benefits of the Weatherization Assistance project should accrue to DOE. These arguments take three basic forms. First, some funding is earmarked, or directed to, DOE's Weatherization Project from other projects and programs. As such, it is almost an artificial construct that the dollars happen to originate elsewhere because fulfilling the fundamental mission is planned, managed, and executed by the Weatherization Project.

Second, DOE's Weatherization project forms the foundation on which all other activities are built. That is, the DOE Weatherization project funds the development and upkeep of the basic core capabilities on which other agencies and organizations draw. If the Weatherization project at DOE did not exist, weatherization activities by States and other agencies would first have to replace these foundational capabilities, which would diminish the benefits from those projects substantially.

Third, the Weatherization project provides key management functions for activities funded by outside organizations. That is, the project provides planning, execution, and evaluation assistance thereby reducing overhead costs for these organizations. As such, more money and assistance are allowed to flow directly to implement project efforts.

Remaining Issues
In discussing the issue of crediting benefits to DOE resulting from leveraged funds, two problems should be noted. First, leveraged funding is being included in estimating those benefits. Comparative measures, such as Btu saved per dollar of project expenditure, should consider these leveraged funds.

Second, project assumptions about what weatherization means, in practice, may not always apply to weatherizations performed with leveraged funds, making the actual field savings estimates more speculative. Currently, the Weatherization Assistance benefits (energy savings) estimates are derived based on certain assumptions about the types of activities being funded and the outputs of those activities. For example, within the project, DOE sets rules on the types of actions (e.g., insulating the attic to a certain R-Value) that are taken when weatherizing a home. From this, the energy savings associated with these actions can be estimated. If a different set of rules applies to the leveraged funds and consequently the leveraged funds pay for actions that result in significantly different outputs, the estimation procedure may no longer adequately characterize the project and the savings might be quite different. At this time, no method is in place to capture the potential differences.

Leveraged Funding Assumptions

For FY 2004, leveraged funding of almost $300 million per year was assumed, based on Weatherization Project projections. A 20% project overhead was subtracted from the total before calculating the number of households weatherized with these funds. Leveraged funding for the *Plus* homes was estimated to total $68.7 million in FY 2004, based on the costs reflected in ORNL's *Meeting The Challenge* report.(3) Based on Weatherization Project projections, PNNL assumed the remainder of the leveraged funds would be used on regular and *Plus* homes in a 60/40 ratio.

Spreadsheet Model Details

The DOE budget and leveraged funding forecasts outlined above were used to determine the number of households weatherized in each category (regular or *Plus*) for each of the four regions (South, Northeast, West, and Midwest) based on the weatherization costs per household and assumptions regarding the use of leveraged funds. Table B-3.5 shows the projection for regular and *Plus* households to be weatherized. The number of households weatherized for each category was assumed to be constant from 2011 through 2030.

Table B-3.5. Projected Regular and *Plus* Households to be Weatherized

	2004	2005	2006	2007	2008	2009	2010	2011
Total Households	231,660	222,395	224,096	225,830	227,599	229,403	231,243	233,119
Regular South	26,441	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Regular Northeast	31,710	26,778	27,006	27,239	27,476	27,717	27,963	28,213
Regular West	28,905	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Regular Midwest	41,434	34,538	34,833	35,134	35,441	35,755	36,076	36,403
Plus South	20,812	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Plus Northeast	25,370	26,778	27.006	27,239	27,476	27,717	27,963	28,213
Plus West	25,280	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Plus Midwest	31,707	34,538	34,833	35,134	35,441	35,755	36,076	36,403

The number of households in each category was multiplied by the estimated savings level for each category (as shown in Table B-3.1). The estimated savings level for each household category was further divided by household type and then by fuel type, based on the Tables B-3.2 and B-3.3. Savings from each household weatherized were assumed to be in effect for 15 years; i.e., savings from households weatherized in 2004 were included in the annual total savings estimates for the years 2004 through 2018.

Project/Technology Consumer Costs:

Because the Weatherization Assistance project is a grant-type project, the recipients of the improvements do not bear the actual investment costs – these costs are paid for with the DOE and leveraged funds. For purposes of modeling the employment and income impacts stemming from the Weatherization Assistance project, an average cost per household weatherized was used to calculate the national employment and income impacts.

Non-Energy Benefits:

A net present value of $161 per household[5] (1989 $), adjusted for inflation, was used for the FY 2004 effort, based on the estimated non-energy benefits resulting from enhanced property values and extended lifetimes of the dwellings, reduced fires, and reduced arrearages. Non-energy benefits associated with employment and environmental externalities are captured elsewhere in this report and therefore are not included in the calculation of non-energy benefits.

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Weatherization Assistance Program* (internal BT document).

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

(3) Schweitzer, M. and J.F. Eisenberg. 2000. *Meeting The Challenge: The Prospect of Achieving 30 Percent Energy Savings Through the Weatherization Assistance Program*. ORNL/CON 479, Draft Analysis, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

(4) Eisenberg, J.F., Oak Ridge National Laboratory. 2001. Special tabulations for the Weatherization Population derived from the 1997 Residential Energy Consumption Survey.

(5) Brown, M.A., L.G. Bery, R.A. Balzer, and E. Faby. 1993. *National Impacts of the Weatherization Assistance Program in Single-Family and Small Multifamily Dwellings*. ORNL/CON-326, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

B.4 State Energy Project

State Energy Project Decision Unit

Project Objective:(1)

The State Energy Project (SEP) provides a supportive framework with sufficient flexibility to enable states to address their energy priorities in concert with national priorities. It supports the federal/state partnerships that are crucial to developing energy policies and deploying energy technologies. SEP emphasizes outreach, technology deployment, and partnerships to accomplish energy-efficiency and renewable energy projects at the state and local level.

Long-Term Goal:(1)

SEP's strategic plan for the 21st century establishes three key goals to be accomplished for 2010: 1) maximize energy, environmental, and economic benefits through increased collaboration at the federal, state, and community level; 2) increase market acceptance of energy-efficiency and renewable energy technologies, practices, and products; and 3) use innovative approaches to reach market segments and meet policy goals not typically addressed by market-based solutions.

Market Segment:

Target Market

- Market Description: The markets include all markets (including buildings, transportation, industry, and power technologies) except new construction and all categories of energy end use.

Methodology:

For the GPRA metrics, the State Energy project project is characterized based on an estimated level of savings per budget dollar, budget request, and leveraged funds. PNNL derived the basic assumptions from a spreadsheet the project provided in FY 1999. We revised the assumptions slightly because of an external peer review conducted by A.D. Little for the FY 2002 GPRA effort.

State Energy Project

Project Type:
Grant

Target Market:
All sectors in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per project dollar

Modeling Tool:
Spreadsheet

Project Manager:
Faith Lambert

Website:
http://www.eren.doe.gov/buildings/state_energy/

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FY 2004 Benefits [d]

Primary Energy Savings (TBtu)

2004	2005	2010	2020
4.0	7.8	24.7	48.7

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.073	0.147	0.490	0.933

Consumer Cost Savings (million $)

2004	2005	2010	2020
25	48	158	352

[d] Benefits estimates for the State Energy Project are the result of both DOE funding and an additional $155 million per year in leverage funds.

Estimated Savings Per Project Dollar

For FY 2004, the estimated savings per project dollar were based on historical information on project dollars from SEP and estimated savings from projects for 1987 through 1993. The SEP provided the original figures. Based on concerns about the historical versus future project mix, as raised in the FY 2002 GPRA effort peer review, savings based on recycling and wood and biomass renewables were removed from the mix. Table B-4.1 presents the resulting energy savings estimates and project dollars by sector.

Table B-4.1. SEP Energy Savings Estimates and Project Dollars

Sector	Total Project Dollars (1987 – 1993)	Non-Electric End-Use Savings (MMBtu/yr)	Electric End-Use Savings (MMBtu/yr)
Residential Buildings	172,142,693	201,405	50,351
Commercial Buildings	369,046,708	283,728	419,316
Industry	78,283,071	249,985	182,408
Transportation	290,320,750	145,297	0
Utilities	21,621,306	58,163	3,859
Education	77,650,746	74,329	40,023
Miscellaneous	87,135,236	0	0
Totals	*1,096,200,511*	*1,012,906*	*695,957*

The end-use savings for each sector in Table B-4.1 were divided by the annual average dollars spent on the project (equal to total project dollars divided by seven years) to yield the average MMBtu savings per project dollar of 0.0044 MMBtu electric and 0.0065 non-electric end-use energy savings, as Table B-4.2 shows.

Table B-4.2. SEP Electric and Non-Electric Savings (**MMBtu/project $**)

Sector	Total End Use	Electric	Non-Electric
Residential Buildings	0.0102	0.0020	0.0082
Commercial Buildings	0.0133	0.0080	0.0054
Industry	0.0387	0.0163	0.0224
Transportation	0.0035	0.0000	0.0035
Utilities	0.0201	0.0012	0.0188
Education	0.0103	0.0036	0.0067
Miscellaneous	0.0000	0.0000	0.0000
Overall	*0.0109*	*0.0044*	*0.0065*

To develop energy savings by fuel type for other fuel savings, PNNL drew upon historical information to estimate savings of natural gas (20%) and fuel oil (80%). The savings also were split between the residential and commercial sectors (with the commercial sector representing savings from industrial, transportation, and utilities) based on the historical split of savings (7% residential and 93% nonresidential).

DOE Funds Available

Because this is a grant project, this activity was assumed not to occur without DOE funding; therefore, we did not apply the NRC (acceleration-to-market) methodology. The FY 2004 planning budget and forecast for FY 2004 to FY 2030 was used to calculate the estimated savings.

Leveraged Funding

Leveraging means that the project efforts are augmented by contributions from organizations other than DOE. These contributions can take the form of direct project-targeted funding or in-kind contributions like staff, research-in-kind, facilities, or other non-monetary resources. In any case, this definition only includes resources that can clearly be attributed to project activities and that are used to augment those activities.

Activities conducted under the banner of the SEP are not only funded by the federal government, through DOE, but also through state matching funds, income generated by SEP activities, and Petroleum Violation Escrow funds.

Rationale for Benefits Attribution

A series of arguments support the overall proposition that the entire benefits of the Weatherization Assistance project should accrue to DOE. These arguments take three basic forms. First, some funding is earmarked or directed to DOE's SEP from other projects and programs. As such, it is almost an artificial construct that the dollars happen to originate elsewhere because fulfilling the fundamental mission is planned, managed, and executed by SEP.

Second, the SEP at DOE forms the foundation on which all other activities are built. That is, the DOE SEP funds the development and upkeep of the basic, core capabilities on which other agencies and organizations draw. If the SEP at DOE did not exist, SEP efforts by States and other agencies would first have to replace these foundational capabilities, which would diminish the benefits from those projects substantially.

Third, the SEP provides key management functions for activities funded by outside organizations; i.e., the project provides planning, execution, and evaluation assistance thereby reducing overhead costs for these organizations. As such, more money and assistance are allowed to flow directly to implement of project efforts.

Remaining Issues

Two problems are related to crediting benefits to DOE resulting from leveraged funds. First, leveraged funding is being included in estimating those benefits. Comparative measures, such as Btu saved per dollar of project expenditure, should consider these leveraged funds.

Second, measurement problems may make savings estimates related to the leveraged funds more speculative. Currently, the benefits (energy savings) estimates are derived based on certain assumptions about the types of activities being funded and the outputs of those activities. If a different set of rules apply to the leveraged funds and consequently the leveraged funds pay for actions that result in significantly different outputs, then the estimation procedure may no longer adequately characterize the project and the savings might be quite different. At this time, no method is in place to capture the potential differences.

Leveraged Funding Assumptions

For FY 2004, funds were assumed to be leveraged at a ratio of $4 for every budget dollar.

Spreadsheet Model Details

To calculate SEP energy savings, the savings estimates of 0.0044 MMBtu electric and 0.0065 non-electric end-use energy savings were applied to the total of the SEP budget and leveraged funding forecasts for each year in the analysis period. These savings were further split by applying the estimated fuel splits and building sector splits, as outlined in the section above, "Estimated Savings per Project Dollar." Savings from each year were assumed to be in effect for 15 years, i.e., savings from 2004 were included in the annual total savings estimates for the years 2004 through 2018.

Project/Technology Consumer Costs:

Because the State Energy Project is a grant-type project, the recipients of the improvements do not bear the actual investment costs – these costs are paid for with the DOE and leveraged funds. For purposes of modeling the employment and income impacts stemming from the State Energy Project, an average cost per grant was used to calculate the national employment and income impacts.

Non-Energy Benefits:

- Cleaner air and water
- Increased jobs
- Enhanced national security
- Increased economic competitiveness in world markets
- Mitigation of global warming.[1]

Source:

(1) *FY 2002 Budget Request – Data Bucket Report for State Formula Grants Program.*

B.5 Rebuild America

Gateway Deployment Decision Unit

Project Objective:[1]

The Rebuild America project builds collaborative partnerships with states and communities to help them develop and implement environmentally and economically sound activities through smarter energy use. Rebuild America connects people, resources, proven ideas, and innovative practices to solve problems. The project provides one-stop shopping for information and assistance on how to plan, finance, implement, and manage retrofit projects to improve buildings energy efficiency and helps communities find other resources on renewable energy applications, efficient new building designs, energy education, and other innovative energy conservation measures.

Rebuild America supports the public/private Energy Smart Schools initiative and competitive Community Energy Grants to support community-wide energy projects.

Long-Term Goal:[3]

The project's long-term goals include saving energy by committing 2.8 billion ft^2 to retrofit by 2010.

Market Segment:

Performance Objective: [3]

- Displaced Technology: The project displaces current design/building practices.
- Performance Target: The target is to reduce heating, cooling and water heat energy use in retrofitted and new buildings by 25%/ft^2 in 2004 and 40%/ft^2 by 2010.

Target Market

- Market Description: Rebuild America helps designated communities design and implement energy-saving projects that respond to their own circumstances and goals, providing access to a portfolio of technical assistance, with a core focus on existing commercial and institutional buildings. The general target market includes new and existing multifamily housing, public/assisted single-family residential units, and commercial buildings, particularly new and existing assembly, health care, lodging, office, and education buildings.

Rebuild America

Project Type:
Whole Building

Target Market:
Existing commercial buildings, multifamily units and residential housing receiving public assistance in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
% change in load

Modeling Tool:
BESET

Project Manager:
Daniel Sze

Website:
http://www.eren.doe.gov/buildings/rebuild/

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FY 2004 Benefits
Primary Energy Savings (TBtu)

2004	2005	2010	2020
1.6	3.0	16.7	20.8

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.027	0.051	0.292	0.354

Consumer Cost Savings (million $)

2004	2005	2010	2020
11	19	113	154

- **Market Size:**[2] The primary market is the commercial building sector, which includes ~68.7 billion square feet of building space; however, the five commercial building types that this project targets make up a total of ~36 billion square feet. The public assistance[1] and multifamily housing that this project also targets make up an additional 27 billion square feet.
- **Penetration Goal:** This activity was assumed not to occur without DOE funding; therefore, the NRC methodology (acceleration-to-market) was not applied. The penetration rates shown in Table B-5.1 are based on project goals of committing 2.8 billion square feet by 2010.

Table B-5.1. Penetration Goals for Rebuild America

Building Type*	Penetration Rates (%)		
	2004	2010	2020
Targeted Commercial Buildings	0.20	2.20	2.60
Multifamily	0.20	2.20	2.60
Single Family	0.01	0.07	0.08
* For all building types, the building vintage is both new and existing and includes both north and south regions.			

Methodology:

Of the 250 million ft² added to the project each year, not all of the square footage per partner is retrofitted in one year. The building retrofits (and actual savings) are assumed to occur evenly over four years. Penetration rates were calculated using the square footage affected by the project as a percentage of the total square footage in the existing building stock.

PNNL applied the load reductions specified in the performance objective to the baseline end-use loads to determine energy savings at the building level. These building-level energy savings were translated into national energy savings using the penetration rates and building stock within the target market and then were adjusted using the most recent budget request information.

Project/Technology Consumer Costs:

- **Cost of Conventional Technology:**[4] Average of $81/ft² for new commercial and multifamily; $0 for existing buildings.
- **Cost of WIP Technology:**[1] $82.60/ft² for new commercial and multifamily; $3/ft² (2001 to 2009), increasing to $4/ft² (2010 to 2030) for existing buildings.
- **Incremental Cost:** 2% above base for new buildings; $3/ft² (2001 to 2009), increasing to $4/ft² (2010 to 2030) for existing buildings.

B.5 Rebuild America

Gateway Deployment Decision Unit

Non-Energy Benefits:[1]

- Revitalized neighborhoods and business districts
- Improving school facilities
- Better low-income housing
- Positive economic impact from keeping dollars locally and increasing property values.

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Rebuild America Program* (includes Energy Smart Schools and Competitively Selected Community Program) (internal BT document).

(2) Commercial building and multifamily square footage numbers come from AEO 2002.

(3) FY 2003 Data Collection interview with the project manager, Daniel Sze, August 20, 2001.

(4) RS Means Company, Inc. 2000. *"RS MEANS Square Foot Costs"*. 22nd Edition, Kingston, MA.

B.6 Information Outreach

Gateway Deployment Decision Unit

Project Objective:[1]

The Information Outreach project provides the technical assistance needed to conduct the various planned activities that will educate target audiences. Specifically, the project conceptualizes, plans, and implements a systematic approach to the marketing and communication objectives and evaluation of the projects it supports.

Long-Term Goal:[1]

By 2010, the project goal is to support long-term success in developing energy-efficient systems and processes and to improve the technology transfer/information exchange process.

Market Segment:

Target Market

- Market Description: The market includes new residential and existing commercial buildings in all climate zones.

Methodology:[2]

A slightly modified version of an evaluation conducted for the Information Outreach project was used to estimate this project's GPRA benefits. This section draws extensively from the report[2] of that evaluation, which follows protocols used by major public relations firms and prominent measurement organizations. The major aspects of the evaluation protocols are as follows:

- Preparation (EERE activities)
  - Adequacy of background information base for designing the project
  - Appropriateness of the message and activity
  - Quality of the message and activity presentations.
- Implementation (distribution effectiveness)
  - Number of messages sent to the media and activities designed
  - Number of activities placed and implemented
  - Number of individuals who receive messages and activities
  - Number of individuals who are responsible for messages and activities.
- Impact (action taken)
  - Number of individuals who learn message content
  - Number of individuals who change opinions
  - Number of individuals who change attitudes

Information Outreach

Project Type:
Information/Education

Target Market:
New residential and existing commercial in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Energy savings per budget dollar

Modeling Tool:
Spreadsheet

Project Manager:
Lani McRae

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FY 2004 Benefits

Primary Energy Savings (TBtu)

2004	2005	2010	2020
14.6	29.0	39.2	36.0

Carbon Equivalent Reductions (MMTCE)

2004	2005	2010	2020
0.249	0.507	0.722	0.636

Consumer Cost Savings (million $)

2004	2005	2010	2020
90	175	247	255

- Number of individuals who behave as desired
- Number of individuals who repeat behavior
- Social and cultural change.

The methodology is summarized as follows (details are contained in Messersmith & Azim 2000):

1. Choose measurable target audiences from the EERE strategic plan (e.g., homeowners, commercial builders, and building retrofit decision-makers) who can implement an EERE strategy, tip, or technology.
2. Determine the energy-savings potential of each representative in the target group from the *BTS Core Data Book*,(3) EERE programmatic experience, and the EIA.
3. Count the total number of impressions from each distribution method and determine how many resulted from commercial builders, building retrofit decision-makers, and individual homeowners (target group) (see Table B-6.1).
4. Use industry-accepted norms to determine what percentage of the target audience who received the message are likely to change their opinion or behavior.
5. Multiply the results in step 4 for each distribution mechanism by the Btu savings potential calculated for each target audience member in step 2.

Table B-6.1. Number of Instances an EERE Key Message was Seen or Heard

Deployment	FY 2000	FY 1999	FY 1998	Cumulative Impact
Conferences (attendees)	46,300	66,650	1,000	113,950
Internet (page views)	1 million	2.4 million	756,426	4.3 million
Media (circulation)	763 million	942 million	1.6 trillion	3.3 trillion
Direct Mail (recipients)	35,812	120,064	30,300	186,176
EREC* (recipients)	17,783	58,984	68,294	145,061
Training (handouts)	0	3,500	872	4,372
Hotline (calls)	0	800	1,623	2,423
Totals	764 million	944 million	1.6 trillion	3.3 trillion
* Energy Efficiency and Renewable Energy Clearinghouse.				

The evaluation prepared for the project by Technologists, Inc. (Messersmith & Azim 2000) estimated total delivered energy savings over a 2½-year period of 34.8 TBtu, resulting in an annual energy savings of 13.92 TBtu. The evaluation assumed that savings lasted for 3 years, after which they are supplanted by activities the decisionmaker would have undertaken in any event. As a result, savings increase over three years to 41.76 TBtu (13.92 x 3) and then stay constant. In the evaluation,(2) the savings are assumed to be 5% residential and 95% commercial, based on the types of decisionmakers the project reaches. The fuel distribution of the savings was assumed to match that of the rest of the BT/WIP portfolio.

Because the budget request for FY04 was significantly less than that for FY03, the savings estimates were budget-adjusted, as described in Section 1.0 of this document.

B.6 Information Outreach

Gateway Deployment Decision Unit

Project/Technology Consumer Costs (PNNL estimate):

Incremental investment costs were developed assuming a 2-year payback period on investment (i.e., an annual energy cost savings of $1.00 implies an initial investment of $2.00).

Non-Energy Benefits:(1)

The challenges of organizing information and communicating effectively are increased by the emergence of new ideas and technologies, the diversity of stakeholders, as well as changing stakeholder needs, assumptions, and perceptions.

Sources:

(1) FY 2002 Budget Request – *Data Bucket Report for Information Outreach Program* (internal BT document).

(2) Messersmith, J., and S.A. Azim. August 2000. *Communication Effectiveness Analysis for GPRA*, Technologists, Inc.

(3) *BTS Core Data Book*. 1999, BT internal document.

B.7 Training and Assistance for Codes

Gateway Deployment Decision Unit

BUILDING ENERGY CODES

Project Objective:

The objective of this activity is to improve the minimum energy efficiency of new buildings and additions and renovations to buildings requiring code permits. The overarching project, Building Energy Codes, provides technical and financial assistance to states to support their adoption or updating and implementation of regularly upgraded model building energy efficiency codes by state and local jurisdictions. (See the Commercial and Residential Building Integration decision unit characterizations in Appendix A of this document). The project also provides technical assistance to federal agencies to adopt and implement upgraded federal building energy codes.

Long-Term Goal: (1)

The project's long-term goal is to improve the minimum energy efficiency of new commercial and multifamily high-rise buildings by 30% to 35% and new low-rise residential buildings by 10%. (See the Commercial and Residential Building Integration decision unit characterizations in Appendix A.)

Market Segment:

The Commercial and Residential Building Integration decision unit characterizations in Appendix A of this document describe the market segment. The project's impact is achieved through a continuum of the three decision units funded separately.

Methodology:

The Commercial and Residential Building Integration decision unit characterizations describe the methodology. For information on this project, see the documentation for Commercial Building Codes and Residential Building Codes projects in Appendix A.

Sources:

(1) FY 2002 Budget – *Data Bucket Report for Residential Buildings Integration R&D Program* (internal BT document).

Training and Assistance for Codes

Project Type:
Information/Education

Target Market:
New residential and commercial buildings and additions and major renovations in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Savings as the percentage of compliance improvement

Modeling Tool:
Spreadsheet

Project Manager:
Jean Boulin

Website:
http://www.energycodes.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
4.7	23.0	72.0	320.7

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.084	0.207	1.445	6.014

Consumer Cost Savings (million $):

2004	2005	2010	2020
31	73	509	2572

B.8 Energy Star

Gateway Deployment Decision Unit

Project Objective:[(1)]

The ENERGY STAR project increases the market penetration of high-efficiency appliances, windows, and lighting technologies through consumer education and voluntary industry partnerships. ENERGY STAR works with manufacturers, national and regional retailers, state and local governments, and more than 100 utilities that serve about half of U.S. households. These partners help the government establish energy efficiency criteria, label products, and promote the manufacture and use of ENERGY STAR products[e].

Long-Term Goal:[(1)]

The project's long-term goal is to achieve a sustained installed base of high-efficiency appliances of 20% by 2010.

Market Segment:

Performance Objective:

- **Displaced Technology:** The project displaces conventional equipment, appliances, and lights.
- **Performance Target:** Performance targets vary by equipment type and size. The following represents a sample of typical ENERGY STAR technologies on the market:
  - Clothes washers – Modified energy factor of 1.26 or greater.
  - Refrigerators – Must exceed the July 1, 2001, minimum federal standards by at least 10%, modeled in NEMS-PNNL as a refrigerator consuming 430 kWh/yr.
  - Electric water heaters – Energy factor ranges from 0.95 to 0.96, modeled in NEMS-PNNL as 0.96.
  - Gas water heaters – Energy factor of 0.60 to 0.65, modeled in NEMS-PNNL as 0.64.
  - Room air conditioners – Must exceed the October 1, 2000, federal standards by at least 10%; the actual energy efficiency ratio depends on the size of the unit.
  - CFLs – Minimum efficacy of 51.3 lumen/watt.
  - Dishwashers – Energy factor of 0.65 or

e http://www.eere.energy.gov/buildings/energystar.html

Energy Star

Project Type:
Market transformation

Target Market:
Commercial sector and residential households with >$45K/yr incomes in all climate zones

End Uses:
All end uses, all fuel types

Unit of Measurement:
Load/efficiency per affected unit

Modeling Tool:
NEMS-PNNL (appliances, air conditioning, and water heating)
BESET (CFLs)

Project Manager:
Richard Karney

Website:
http://www.energystar.gov

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FY 2004 Benefits
Primary Energy Savings (TBtu):

2004	2005	2010	2020
18.2	30.5	143.8	598.0

Carbon Equivalent Reductions (MMTCE):

2004	2005	2010	2020
0.311	0.541	2.846	11.463

Consumer Cost Savings (million $):

2004	2005	2010	2020
127	212	1162	5630

greater; typically uses 400 to 450 kWh/year.

Target Market

- **Market Description:** The market is determined by the project equipment. For FY 2004, the following equipment is characterized (residential):
  - Clothes washers
  - Refrigerators
  - Electric water heaters
  - Gas water heaters
  - Room air conditioners
  - CFLs
  - Dishwashers.

Methodology

PNNL modeled clothes washers, refrigerators, electric water heaters, gas water heaters, room air conditioners, and dishwashers in NEMS-PNNL using input from EIA's *Annual Energy Outlook 2001,*[2] based on a project goal of ENERGY STAR appliances achieving 20% of the market share by 2010. We modeled ENERGY STAR CFLs in BESET and assumed they would capture 10.5% of incandescent sales in the residential sectors by 2020 (based on goal of capturing 20% of the installed base). It is assumed that ENERGY STAR CFLs will penetrate the high usage residential fixtures where most of the energy is consumed; 76.4% of the energy consumed by residential incandescent lighting is consumed in 28.3% of the sockets[f]. Thus a 20% installed base will impact up to 54% (20%/28.3%*76.4%) of the consumption. However, because it is highly unlikely that the CFLs will actually take all the high utilization sockets and none of the lower utilization sockets, the impact was assumed to be only 37%. This activity was assumed not to occur without DOE funding; therefore, the NRC (acceleration-to-market) methodology was not applied.

Energy Star Technologies Modeled in NEMS-PNNL

Market transformation projects, such as ENERGY STAR, attempt to accelerate market penetration of existing high-efficiency technologies. From a modeling standpoint, these efforts translate into reducing the consumer's discount rate for these energy-efficient technologies. The discount rate for a technology significantly impacts how a consumer determines the present value of the benefits and costs associated with this technology. For ENERGY STAR technologies, most of the costs are incurred at the time the technology is purchased, while most of the energy-saving benefits occur in the future over time. If the discount rate for a given technology is particularly high, the value a consumer places on these future energy-saving benefits will be low relative to the weight the consumer places on present costs. Therefore, to facilitate project modeling , one goal of the ENERGY STAR project is to reduce these discount rates by providing additional information about the potential benefits to the consumer.

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[f] http://enduse.lbl.gov/Info/LBNL-39102.pdf . Calculated from data in Table 2.7.

Within NEMS-PNNL, the two modeling parameters determining the discount rate are labeled Beta1 and Beta2. Beta1 is used as multiplicative factor with the initial cost of the appliance, and Beta2 is used to multiply the annual energy cost. The sum of the two products (i.e., Beta1 * initial cost + Beta2 * operating cost) is used in the logit specification to yield market shares for each technology. As a rough approximation, the ratio of Beta1/Beta2 can be interpreted as the consumer discount rate for a specific technology. In the residential NEMS-PNNL module, the Beta1 and Beta2 coefficients vary among technologies, as do the resulting discount rates. For example, the implied discount rate for refrigerators is 16%, while the discount rate is estimated to be >80% for electric water heaters.

The modifications to the NEMS input file (RTEKTY) required to estimate energy savings in NEMS-PNNL for each technology in an ENERGY STAR project are described in the following sections. The assumed reduction in the discount rate (from ENERGY STAR support) is modeled by reducing the Beta 1 parameter. The baseline assumptions made by the EIA, the changes in the Beta1 coefficients, and the resulting changes in the market shares for the most energy-efficient products are documented by technology.

Modeling the Market for Energy Star Clothes Washers

Technology Choices Available in the Model

Modeling the energy savings of clothes washers is complex because energy can be saved by reducing the consumption of the motor, hot water use, or dryer energy use. The most efficient new technology is the horizontal-axis design, which achieves the bulk of its energy savings by reducing hot water use.

The residential NEMS-PNNL input file (RTEKTY) includes a column of factors that relate to hot water. The (unitless) factors can be used to adjust the hot water load associated with clothes washers and dishwashers. In preliminary model runs, the values associated with clothes washers appeared to be too low compared with the information supplied by Lawrence Berkeley National Laboratory (LBNL) in support of an efficiency standard for clothes washers. Therefore, these factors were adjusted from 0.67 to 2.00 for vertical-axis machines. The coefficient for the horizontal-axis machine was increased from 0.24 to 0.40. The value for the vertical axis machine was estimated by making runs of the model with and without *any* hot water and observing the resulting energy consumption. The LBNL analysis suggests that 80% to 90% of the energy consumption of clothes washers is attributable to water heating. Table B-8.1 shows the original and revised NEMS-PNNL inputs for clothes washers.

Market Share Estimates

With the support of the ENERGY STAR project, the Beta1 parameter, which impacts the resulting market share of each clothes washer technology, was modified from -0.03811 to -0.0101 based on this product's project goals. Table B-8.2 shows the market share results of the NEMS-PNNL model runs for clothes washers.

Modeling the Market for Energy Star Refrigerators

Technology Choices Available in Model

EIA uses four separate models to represent the range of energy efficiencies in the refrigerator market. The first three models are conventional top-mount freezer models with a total capacity of 18 cubic feet. The fourth is a through-the-door model (for water and ice) and does not compete with the first three models. The market share of the through-the-door model is a constant 27% over the forecast horizon. A review of Arthur D. Little's[(3)] (ADL 1998) efficiency and cost forecasts, as well as a recent paper from Oak Ridge National Laboratory[(4)] (ORNL, Vineyard and Sand 1998), suggests some changes to EIA's assumptions used in the *Annual Energy Outlook 2001*[(2)] projection are warranted.

Table B-8.1. Original and Revised NEMS-PNNL Inputs for Energy Star Clothes Washers

Original NEMS Inputs						
Technology	Start Yr	End Yr	Water Coeff.	Energy Factor	Installed Cost ($)	Type
1	1997	2020	0.67	2.71	90	V-Axis
2	1997	2004	0.67	3.88	645	V-Axis
3	2005	2020	0.67	3.88	590	V-Axis
4	1997	2020	0.24	4.45	800	H-Axis
5	2005	2020	0.24	5.27	800	H-Axis
6	2015	2020	0.24	5.44	800	H-Axis
NEMS-PNNL Inputs						
1	1997	2020	2.0	2.71	490	V-Axis
2	1997	2004	2.0	3.88	645	V-Axis
3	2005	2020	2.0	3.88	590	V-Axis
4	1997	2020	0.4	4.45	800	H-Axis
5	2005	2020	0.4	5.27	800	H-Axis
6	2015	2020	0.4	5.44	800	H-Axis

Table B-8.2. Energy Star Clothes Washer Market Shares by Technology Estimated by NEMS-PNNL

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0000	0.0927	0.0000	0.0923
2	0.0000	0.0904	0.0000	0.0900
3	0.0000	0.0814	0.0000	0.0804
4	0.0000	0.0794	0.0000	0.0794
5	0.0000	0.0813	0.0000	0.0812
6	0.0000	0.0799	0.0000	0.0797
7	0.0000	0.0801	0.0000	0.0791
8	0.0000	0.0831	0.0000	0.0833
9	0.0000	0.0826	0.0000	0.0830

Note: Results shown are for new housing units; replacement shares are generally within 0.5 % of values shown here.

As part of the EIA forecast, the 2001 standard (Model 1) was assumed to yield no increase in cost. Table B-8.3 shows the EIA efficiency and cost assumptions, which appear to contradict some of the ADL findings. The ADL performance/cost characteristics information suggests that a 460-kWh/yr unit would have an installed cost of $580 to $700. To be conservative, an installation cost of $600 could be assumed. Because a 478-kWh/yr

Table B-8.3. Refrigerator Efficiency and Costs: *Annual Energy Outlook 2001*

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0
1	2002	2020	478	530.0	480.0
2	1997	2001	660	550.0	500.0
2	2002	2020	460	550.0	500.0
3	1993	2001	518	850.0	800.0
3	2002	2020	460	550.0	500.0
3	2005	2020	400	700.0	650.0
4	1993	2001	843	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8

unit is nearly as efficient as the 460-kWh/yr unit, one would expect it would be only negligibly less expensive. Using this logic, the cost of the 478-kWh/yr unit is assumed to be ~$580. These revised assumptions are included in Table B-8.4.

Table B-8.4. Refrigerator Efficiency and Costs: NEMS-PNNL

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0
1	2002	2020	478	580.0	480.0
2	1997	2001	660	550.0	500.0
2	2002	2020	460	600.0	550.0
3	1997	2001	518	850.0	800.0
3	2002	2020	460	600.0	550.0
3	2005	2020	400	700.0	650.0
4	1997	2001	843	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8

The ADL report(3) suggests that a 460-kWh/yr model represents a typical model after 2002. A high-efficiency model is specified to consume 400 kWh per year. However, this specification is for a 20-cubic-foot model rather than 18 cubic feet. ADL suggests a cost differential of $100 to $120 between these two models.

Vineyard and Sand (1998)(4) add some support to this revision in the cost structure. They start with a "1996 model baseline unit" of 20 cubic feet that uses 613 kWh/year. The baseline is already 16% more efficient than the 1993 standard (2.01 kWh/day) resulting from the National Appliance Energy Conservation Act.(5) From this baseline, they focus on two high-efficiency designs. The most aggressive design would reduce energy by 273 kWh/yr at a retail cost increase of ~$270. A more cost-effective unit would consume 1.16 kWh/day (423 kWh/yr) at a projected cost increase of $106.

Given this information, the resulting estimated cost increase of $100 between the 460- and 400-kWh/day units appears to be more reasonable (see Table B-8.4) than EIA's incremental cost of $150. The ORNL baseline unit is less efficient than the 2001 standard and achieves a 30% energy reduction with a little more than a $100 cost increase. This suggests that the 13% efficiency improvement (460 to 400) between models 2 and 3 could be achieved for $100 or less.

Market Share Estimates

The *Annual Energy Outlook 2001*(2) baseline parameters that determined the market share for high efficiency clothes washers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0229}{-0.1207} \approx discount\ rate = 19\%$$

B.8 Energy Star

Gateway Deployment Decision Unit

The ENERGY STAR project is assumed to increase the market share of the 400-kWh/yr refrigerator. With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0055}{-0.1207} \approx discount\ rate^{E-Star} = 5\%$$

The resulting NEMS-PNNL market shares for ENERGY STAR refrigerators for 2005 and 2010 are shown in Table B-8.5.

Modeling the Market for Energy Star Hot Water Heaters

PNNL made separate sets of NEMS-PNNL runs for electric water heaters and gas water heaters to model the effects of ENERGY STAR technologies.

Electric Water Heating Technologies Available in Model

Table B-8.6 shows EIA's key NEMS inputs for the *Annual Energy Outlook 2001*.[2] With these assumed costs, the model projects a zero share for heat pump water heaters.

Table B-8.5. Energy Star Project – Refrigerators
(market share of 400-kWh/yr units)

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0427	0.2068	0.0426	0.2064
2	0.0409	0.2003	0.0400	0.1971
3	0.0337	0.1727	0.0329	0.1698
4	0.0326	0.1687	0.0327	0.1689
5	0.0342	0.1748	0.0341	0.1744
6	0.0330	0.1702	0.0329	0.1696
7	0.0329	0.1698	0.0322	0.1668
8	0.0355	0.1801	0.0356	0.1805
9	0.0354	0.1793	0.0357	0.1807

Table B-8.6. Key NEMS-PNNL Inputs for Electric Water Heaters (*Annual Energy Outlook 2001*)

Technology	Start Yr	End Yr	Energy Factor	Installed Cost ($)	Type
1	1997	2020	0.86	350	Resistance
2	1997	2020	0.88	350	Resistance
3	1997	2020	0.95	575	Resistance
4	1997	2020	2.60	1,025	Heat Pump
5	1997	2020	2.00	2,600	Heat Pump
6	2005	2020	0.89	350	Resistance
7	2005	2020	0.96	475	Resistance
8	2005	2020	2.00	900	Heat Pump
9	2015	2020	0.90	400	Resistance
10	2015	2020	0.96	425	Resistance
11	2015	2020	2.20	800	Heat Pump

The ENERGY STAR project was assumed to target high-efficiency electric water heaters whose efficiencies exceed 0.9. As Table B-8.6 shows, two such units are shown, with efficiencies of 0.95 and 0.96. By 2005, the installed cost of the high-efficiency unit (at the 0.96 efficiency level) is assumed to fall to $475.

Market Share Estimates for Electric Water Heaters

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency clothes washers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.01619}{-0.01952} \approx discount\ rate = 83\%$$

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0082}{-0.01952} \approx discount\ rate^{E-Star} = 42\%$$

Table B-8.7 shows the specific NEMS-PNNL market share results.

Table B-8.7. NEMS-PNNL Results for Energy Star Electric Water Heaters (national market shares for new single-family homes)

Efficiency Level	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
0.95	0.0110	0.0540	0.0110	0.0540
0.96	0.0560	0.1280	0.0560	0.1270
Total	0.0670	0.1820	0.0670	0.1810
Note: Results shown are for new, single-family housing units; replacement shares are generally within 2% of the values shown here.				

Gas Water Heating Technology Choices Available in Model

Table B-8.8 shows EIA's key NEMS-PNNL inputs for the *Annual Energy Outlook 2001*.[2] The ENERGY STAR project was assumed to promote high-efficiency gas water heaters whose energy factors are 0.6 or higher. As Table B-8.8 shows, two such units are shown, with energy factors of 0.6 and 0.63. By 2005, the installed cost of the high-efficiency unit (at the 0.60 energy factor level) is assumed to fall from $400 to $375.

Market Share Estimates for Gas Water Heaters

The *Annual Energy Outlook 2001*[2] baseline parameters that determined the market share for high-efficiency gas water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.05393}{-0.1136} \approx discount\ rate = 47\%$$

Table B-8.8. Key NEMS-PNNL Inputs for Gas Water Heaters

Technology	Start Yr	End Yr	Energy Factor	Installed Cost	Type
1	1997	2020	0.54	$340	Noncondensing
2	1997	2020	0.58	$370	Noncondensing
3	1997	2004	0.60	$400	Noncondensing
4	2005	2020	0.60	$375	Noncondensing
5	1997	2020	0.86	$2360	Condensing
6	2005	2014	0.86	$2000	Condensing
7	2015	2020	0.86	$1800	Condensing
8	2005	2014	0.63	$450	Noncondensing
9	2015	2020	0.63	$425	Noncondensing
10	2015	2020	0.70	$500	Noncondensing

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0323}{-0.1136} \approx discount\ rate^{E-Star} = 28\%$$

Table B-8.9 shows the specific NEMS-PNNL market share results.

Table B-8.9. NEMS-PNNL Results for Energy Star Gas Water Heaters (national market shares for new, single-family homes)

Efficiency Level	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
0.60	0.307	0.387	0.315	0.384
0.63	0.011	0.068	0.011	0.066
Total	0.318	0.455	0.326	0.450

Energy Star Room Air Conditioners

Technology Choices Available in Model

For the year 2005, EIA assumes that efficiencies of room air conditioners will range from a low of 2.83 COP (seasonal energy efficiency ratio) to a high of 3.52 COP. In the *Annual Energy Outlook 2001*(2) input file for the residential NEMS-PNNL module, two models were at the low end of this range (COP = 2.83, COP = 2.93), while two models were at the high end of the range (COP = 3.22, COP = 3.43). To achieve a more realistic set of choices, a model with an intermediate efficiency of 3.11 was added and the unit at the 2.93 (COP) level was dropped. The increase in cost to go from a COP of 2.83 to 2.93 was assumed to be $30. Table B-8.10 shows both the original NEMS-PNNL input data and the revised data.

The high-efficiency units with a COP >3.4 were assumed to fall under the ENERGY STAR project. In the base case, the combined market share for the units with COPs of 3.43 and 3.52 were <1%. The split in market share between the lowest and intermediate efficiency unit (COP = 2.83 and 3.11, respectively) was generally ~75%/25% in favor of the lowest efficiency model.

Market Share Estimates

The *Annual Energy Outlook 2001*(2) baseline parameters that determined the market share for high-efficiency room air conditioners are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0170}{-0.0120} \approx discount\ rate > 100\%$$

Table B-8.10. NEMS-PNNL Input Parameters for Room Air Conditioners

Technology	Start Year	End Year	Seasonal COP	SEER*	Installed Cost
Annual Energy Outlook 2001 and GPRA Baseline					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	2.93	10.00	$500
4	2005	2020	2.93	10.00	$490
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.43	11.71	$760
7	2015	2020	3.22	10.99	$600
Revised NEMS-PNNL Inputs					
1	1997	2000	2.55	8.70	$450
2	2001	2020	2.83	9.66	$450
3	1997	2004	3.11	10.61	$530
4	2005	2020	3.11	10.61	$520
5	1997	2020	3.43	11.71	$760
6	2005	2020	3.52	12.01	$760
7	2015	2020	3.22	10.99	$600
*SEER – seasonal energy efficiency ratio.					

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0070}{-0.0120} \approx discount\ rate^{E-Star} = 58\%$$

Table B-8.11 shows the specific NEMS-PNNL market share results for the high-efficiency model.

Table B-8.11. NEMS-PNNL Results for Energy Star Room Air Conditioners (market shares for new, single-family homes)

Census Division	2005		2010	
	Baseline	Energy Star	Baseline	Energy Star
1	0.0083	0.1301	0.0083	0.1299
2	0.0085	0.1323	0.0085	0.1321
3	0.0085	0.1319	0.0084	0.1314
4	0.0084	0.1314	0.0084	0.1312
5	0.0091	0.1396	0.0091	0.1395
6	0.0091	0.1402	0.0091	0.1398
7	0.0101	0.1522	0.0099	0.1501
8	0.0085	0.1327	0.0085	0.1327
9	0.0084	0.1314	0.0084	0.1317

Modeling the Market for Energy Star Dishwashers

Technology Choices Available in Model

The NEMS-PNNL baseline (*Annual Energy Outlook 2001*)[(2)] data input for the year 2005 shows three dishwashers, with energy factors 0.46, 0.59, and 0.71. Table B-8.12 shows the associated costs of these units. Given the cost structure and logit choice parameters, the model suggests that consumers select slightly more than 6% of dishwashers with the 0.59 energy factor and virtually none of the very high efficiency units.

Table B-8.12. Key NEMS-PNNL Data Inputs for Dishwashers

Census Division	Initial Yr	Ending Yr	Water Co-Efficiency	Energy Factor	Installed Cost ($)
1	1997	2020	0.80	0.46	350
2	1997	2004	0.80	0.59	500
3	2005	2020	0.80	0.59	450
4	1997	2004	0.78	0.71	700
5	2005	2014	0.78	0.71	600
6	2015	2020	0.78	0.71	500
7	2015	2020	0.80	0.60	400

Market Share Estimates

The *Annual Energy Outlook 2001*[(2)] baseline parameters that determined the market share for high efficiency dishwashers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.02738}{-0.02413} \approx discount\ rate > 100\%$$

B.8 Energy Star

Gateway Deployment Decision Unit

With the support of the ENERGY STAR project, the parameters impacting market share were assumed to change in the following manner, based on project goals:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.01338}{-0.02413} \approx discount\ rate^{E-Star} = 55\%$$

Table B-8.13 shows the specific NEMS-PNNL market share results for the two high-efficiency models.

Table B-8.13. Energy Star Project Dishwashers (estimated market shares for high-efficiency dishwashers)

Census Division	2005				2010			
	Baseline		Energy Star		Baseline		Energy Star	
	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71	EF=.59	EF=.71
1	0.0683	0.0012	0.2219	0.0322	0.0682	0.0012	0.2217	0.0321
2	0.0678	0.0012	0.2207	0.0318	0.0677	0.0012	0.2204	0.0317
3	0.0659	0.0011	0.2157	0.0305	0.0656	0.0011	0.2151	0.0304
4	0.0654	0.0011	0.2146	0.0302	0.0654	0.0011	0.2145	0.0304
5	0.0658	0.0011	0.2156	0.0305	0.0654	0.0011	0.2145	0.0304
6	0.0655	0.0011	0.2148	0.0303	0.0658	0.0011	0.2156	0.0305
7	0.0656	0.0011	0.2150	0.0303	0.0653	0.0011	0.2144	0.0302
8	0.0662	0.0011	0.2166	0.0308	0.0663	0.0012	0.2168	0.0308
9	0.0661	0.0011	0.2164	0.0307	0.0663	0.0012	0.2169	0.0308

EF – energy factor.

Energy Star Projects Modeled with BESET

Energy Star CFLs

PNNL modeled the ENERGY STAR CFLs in BESET and assumed they would capture 10.5% of incandescent sales in the residential sectors by 2020 (based on market penetration goal of capturing 20% of the installed base). ENERGY STAR CFLs were assumed to penetrate the high-use part of the market where 76.4% of the residential lighting energy is consumed (e.g., rooms such as kitchens and living rooms). The sockets in high-use areas (28.3% of the total sockets) will use roughly the same fraction of the lamps (i.e., 28.3% of the sockets consume 76.4% of the lighting energy use). A sales fraction of 10.5% will yield a long-term installed base of 20% in high-use sockets.

Performance Objective:

- **Displaced Technology:** Incandescent light bulbs.
- **Performance Target:** 51.3 lumens/watt.

Market Penetration:

- **Target Market:** Residential sector.

B.8 Energy Star

Gateway Deployment Decision Unit

- **Market Penetration Goal:** 10.5% of incandescent sales in the residential sectors by 2020 (see Figure B-8.1).

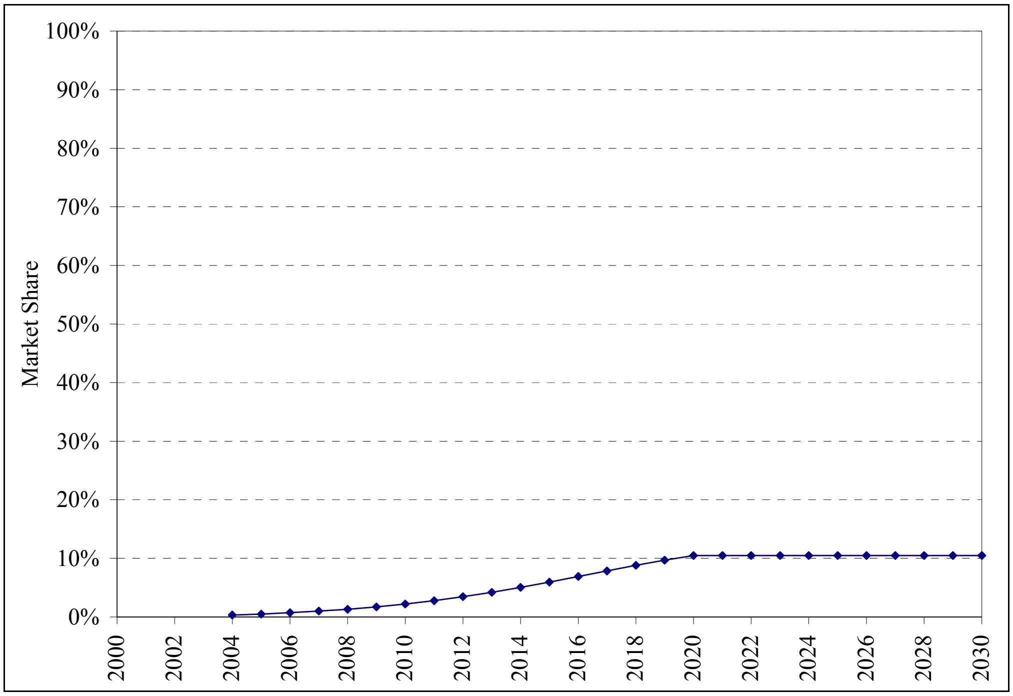

Figure B-8.1. Market Penetration Curves for Energy Star CFLs

Project/Technology Consumer Costs (PNNL Estimate):

- Cost of Conventional Technology: $0.75
- Cost of WIP Technology: Assumed to decrease over study period from approximately $7.00 per CFL in 2004 declining to $3.00 per CFL in 2030.
- Incremental Cost: Varies by year.

Non-Energy Benefits:(1)

- Increased comfort for residential homeowners
- Decreased times spent changing out incandescent lamps
- Water and water bill savings from higher efficiency dishwashers and clothes washers
- Increased amenities with clothes washers, also decreased time required for dryer cycle
- Higher profits for manufacturers.

B.8 Energy Star

Gateway Deployment Decision Unit

Sources:

(1) *FY 2002 Budget Request – Data Bucket Report for Energy Star Program* (internal BTS document).

(2) *Annual Energy Outlook 2001*. 2001. Energy Information Administration, Washington, D.C.

(3) Arthur D. Little, Inc. (ADL). 1998. "EIA Technology Forecast Updates – Residential and Commercial Building Technologies, Reference Case."

(4) Vineyard, E.A. and J.R. Sand. 1998. "Fridge of the Future: Designing a One Kilowatt-Hour/Day Domestic Refrigerator Freezer." In *1998 ACEEE Summer Study Proceedings*.

(5) National Appliance Energy Conservation Act of 1987, Public Law 100-12.

Appendix C – Baseline Inputs for BESET

To obtain the GPRA metrics for FY 2004, the following baseline scenario and inputs were used. The development of these inputs is discussed in the GPRA Methodology section within the body of this document. This information is common to all projects analyzed within BESET.

C.1 Building Stock

Building stock estimates are used to estimate each project's total energy savings at the national level. Residential and commercial new and existing building stock totals for all years through 2020 were provided by EIA's *Annual Energy Outlook 2002*. The stock estimates were developed for each market segment (e.g., building type, building vintage, and region) based on the assumptions outlined in Section 1.0, "GPRA Methodology." The base year is 2004, and all construction beginning with 2004 is considered "new." Tables C.1 through C.14 present the in-year building stock forecasts by building type, building vintage, and region.

Abbreviations used in the tables in this appendix are as follows:

CAC	central air conditioner
CFL	compact fluorescent light
EE	energy efficient
Elec	electric
FA	forced air
Fluor	fluorescent
Furn	furnace
HE	high efficiency
HID	high-intensity discharge
HP	heat pump
Incan	incandescent
Room	room air conditioner
Std	standard
WH	water heater

C.1.1 Commercial Building Stock Forecasts

Table C.1. Commercial Assembly Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	4.24	2.95	0.10	0.08
2005	4.18	2.91	0.10	0.08
2006	4.12	2.87	0.10	0.08
2007	4.06	2.82	0.10	0.08
2008	4.00	2.78	0.10	0.08
2009	3.94	2.74	0.10	0.08
2010	3.88	2.70	0.10	0.08
2011	3.82	2.65	0.10	0.08
2012	3.75	2.61	0.10	0.08
2013	3.69	2.56	0.10	0.08
2014	3.63	2.52	0.10	0.09
2015	3.56	2.48	0.10	0.09
2016	3.50	2.43	0.10	0.09
2017	3.43	2.39	0.11	0.09
2018	3.37	2.34	0.11	0.09
2019	3.30	2.29	0.11	0.09
2020	3.24	2.25	0.11	0.09
2021	3.18	2.21	0.11	0.09
2022	3.12	2.16	0.11	0.09
2023	3.06	2.12	0.11	0.09
2024	3.00	2.08	0.11	0.09
2025	2.94	2.04	0.11	0.09
2026	2.89	2.01	0.11	0.09
2027	2.83	1.97	0.11	0.09
2028	2.78	1.93	0.11	0.09
2029	2.72	1.89	0.11	0.09
2030	2.67	1.86	0.11	0.09

Table C.2. Commercial Education Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	5.32	3.70	0.19	0.15
2005	5.24	3.64	0.18	0.15
2006	5.16	3.58	0.18	0.15
2007	5.07	3.53	0.18	0.14
2008	4.99	3.47	0.17	0.14
2009	4.91	3.41	0.17	0.14
2010	4.82	3.35	0.17	0.14
2011	4.74	3.29	0.16	0.13
2012	4.65	3.23	0.16	0.13
2013	4.57	3.17	0.16	0.13
2014	4.48	3.12	0.16	0.13
2015	4.40	3.06	0.15	0.12
2016	4.31	3.00	0.15	0.12
2017	4.23	2.94	0.14	0.12
2018	4.15	2.88	0.13	0.11
2019	4.06	2.82	0.13	0.10
2020	3.98	2.77	0.12	0.10
2021	3.90	2.71	0.13	0.11
2022	3.82	2.66	0.13	0.11
2023	3.75	2.60	0.13	0.11
2024	3.67	2.55	0.13	0.11
2025	3.60	2.50	0.13	0.11
2026	3.53	2.45	0.13	0.11
2027	3.46	2.40	0.13	0.11
2028	3.39	2.36	0.13	0.11
2029	3.32	2.31	0.13	0.11
2030	3.26	2.26	0.13	0.11

Table C.3. Commercial Food Sales Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	0.44	0.31	0.01	0.01
2005	0.44	0.31	0.01	0.01
2006	0.44	0.30	0.01	0.01
2007	0.43	0.30	0.01	0.01
2008	0.43	0.30	0.01	0.01
2009	0.42	0.29	0.01	0.01
2010	0.42	0.29	0.01	0.01
2011	0.41	0.29	0.01	0.01
2012	0.41	0.28	0.01	0.01
2013	0.40	0.28	0.01	0.01
2014	0.39	0.27	0.01	0.01
2015	0.39	0.27	0.01	0.01
2016	0.38	0.27	0.01	0.01
2017	0.38	0.26	0.01	0.01
2018	0.37	0.26	0.01	0.01
2019	0.37	0.25	0.01	0.01
2020	0.36	0.25	0.01	0.01
2021	0.35	0.25	0.01	0.01
2022	0.35	0.24	0.01	0.01
2023	0.34	0.24	0.01	0.01
2024	0.34	0.23	0.01	0.01
2025	0.33	0.23	0.01	0.01
2026	0.33	0.23	0.01	0.01
2027	0.32	0.22	0.01	0.01
2028	0.32	0.22	0.01	0.01
2029	0.31	0.22	0.01	0.01
2030	0.31	0.21	0.01	0.01

Table C.4. Commercial Food Service Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	0.91	0.63	0.02	0.02
2005	0.90	0.62	0.02	0.02
2006	0.89	0.62	0.02	0.02
2007	0.88	0.61	0.02	0.01
2008	0.87	0.60	0.02	0.01
2009	0.85	0.59	0.02	0.01
2010	0.84	0.59	0.02	0.02
2011	0.83	0.58	0.02	0.02
2012	0.82	0.57	0.02	0.01
2013	0.81	0.56	0.02	0.01
2014	0.80	0.55	0.02	0.01
2015	0.79	0.55	0.02	0.01
2016	0.77	0.54	0.02	0.01
2017	0.76	0.53	0.02	0.01
2018	0.75	0.52	0.02	0.01
2019	0.74	0.51	0.02	0.02
2020	0.73	0.50	0.02	0.02
2021	0.72	0.50	0.02	0.01
2022	0.70	0.49	0.02	0.01
2023	0.69	0.48	0.02	0.01
2024	0.68	0.47	0.02	0.01
2025	0.67	0.47	0.02	0.01
2026	0.66	0.46	0.02	0.01
2027	0.65	0.45	0.02	0.01
2028	0.64	0.44	0.02	0.01
2029	0.63	0.44	0.02	0.01
2030	0.62	0.43	0.02	0.01

Table C.5. Commercial Health Care Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	1.17	0.81	0.04	0.03
2005	1.16	0.81	0.04	0.03
2006	1.15	0.80	0.04	0.03
2007	1.14	0.79	0.04	0.03
2008	1.13	0.78	0.04	0.03
2009	1.12	0.78	0.04	0.03
2010	1.10	0.77	0.04	0.03
2011	1.09	0.76	0.04	0.03
2012	1.08	0.75	0.04	0.03
2013	1.06	0.74	0.04	0.04
2014	1.05	0.73	0.04	0.04
2015	1.03	0.72	0.05	0.04
2016	1.02	0.71	0.05	0.04
2017	1.00	0.70	0.05	0.04
2018	0.99	0.69	0.05	0.04
2019	0.97	0.67	0.05	0.04
2020	0.95	0.66	0.05	0.04
2021	0.94	0.65	0.05	0.04
2022	0.92	0.64	0.05	0.04
2023	0.91	0.63	0.05	0.04
2024	0.89	0.62	0.05	0.04
2025	0.88	0.61	0.05	0.04
2026	0.86	0.60	0.05	0.04
2027	0.85	0.59	0.05	0.04
2028	0.83	0.58	0.05	0.04
2029	0.82	0.57	0.05	0.04
2030	0.81	0.56	0.05	0.04

Table C.6. Commercial Lodging Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	2.54	1.76	0.08	0.06
2005	2.51	1.74	0.07	0.06
2006	2.48	1.72	0.07	0.06
2007	2.45	1.70	0.07	0.06
2008	2.42	1.69	0.07	0.06
2009	2.40	1.66	0.08	0.06
2010	2.37	1.64	0.08	0.07
2011	2.33	1.62	0.08	0.07
2012	2.30	1.60	0.09	0.07
2013	2.27	1.58	0.09	0.07
2014	2.24	1.56	0.09	0.07
2015	2.21	1.53	0.09	0.07
2016	2.17	1.51	0.09	0.07
2017	2.14	1.49	0.09	0.07
2018	2.10	1.46	0.09	0.07
2019	2.07	1.44	0.09	0.07
2020	2.03	1.41	0.09	0.07
2021	2.00	1.39	0.09	0.07
2022	1.97	1.37	0.09	0.07
2023	1.94	1.35	0.09	0.07
2024	1.90	1.32	0.09	0.07
2025	1.87	1.30	0.09	0.07
2026	1.84	1.28	0.09	0.07
2027	1.81	1.26	0.09	0.07
2028	1.78	1.24	0.09	0.07
2029	1.76	1.22	0.09	0.07
2030	1.73	1.20	0.09	0.07

Table C.7. Commercial Mercantile and Service Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	8.56	5.95	0.21	0.17
2005	8.46	5.88	0.20	0.16
2006	8.36	5.81	0.20	0.16
2007	8.26	5.74	0.19	0.16
2008	8.16	5.67	0.19	0.16
2009	8.06	5.60	0.20	0.16
2010	7.96	5.53	0.20	0.16
2011	7.85	5.45	0.20	0.16
2012	7.74	5.38	0.20	0.16
2013	7.63	5.30	0.19	0.16
2014	7.52	5.23	0.19	0.15
2015	7.41	5.15	0.19	0.15
2016	7.30	5.07	0.19	0.15
2017	7.18	4.99	0.19	0.16
2018	7.06	4.91	0.20	0.16
2019	6.95	4.83	0.20	0.16
2020	6.83	4.74	0.19	0.16
2021	6.71	4.67	0.19	0.16
2022	6.61	4.59	0.19	0.16
2023	6.50	4.52	0.19	0.16
2024	6.39	4.44	0.19	0.16
2025	6.29	4.37	0.19	0.16
2026	6.19	4.30	0.19	0.16
2027	6.08	4.23	0.19	0.16
2028	5.99	4.16	0.19	0.16
2029	5.89	4.09	0.19	0.16
2030	5.79	4.02	0.19	0.16

Table C.8. Commercial Office—Large Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.71	2.58	0.08	0.07
2005	3.67	2.55	0.08	0.06
2006	3.64	2.53	0.08	0.06
2007	3.61	2.51	0.07	0.06
2008	3.57	2.48	0.07	0.06
2009	3.54	2.46	0.07	0.06
2010	3.50	2.43	0.07	0.06
2011	3.46	2.41	0.08	0.06
2012	3.42	2.38	0.08	0.06
2013	3.38	2.35	0.08	0.07
2014	3.34	2.32	0.08	0.07
2015	3.30	2.29	0.08	0.07
2016	3.26	2.26	0.08	0.07
2017	3.21	2.23	0.08	0.07
2018	3.17	2.20	0.08	0.07
2019	3.12	2.17	0.09	0.07
2020	3.07	2.13	0.09	0.07
2021	3.03	2.10	0.08	0.07
2022	2.98	2.07	0.08	0.07
2023	2.94	2.04	0.08	0.07
2024	2.90	2.01	0.08	0.07
2025	2.86	1.99	0.08	0.07
2026	2.82	1.96	0.08	0.07
2027	2.78	1.93	0.08	0.07
2028	2.74	1.90	0.08	0.07
2029	2.70	1.87	0.08	0.07
2030	2.66	1.85	0.08	0.07

Table C.9. Commercial Office—Small Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.52	2.44	0.09	0.08
2005	3.48	2.42	0.09	0.07
2006	3.43	2.39	0.08	0.07
2007	3.39	2.36	0.08	0.07
2008	3.35	2.33	0.08	0.06
2009	3.31	2.30	0.08	0.07
2010	3.26	2.27	0.08	0.07
2011	3.22	2.24	0.08	0.07
2012	3.18	2.21	0.09	0.07
2013	3.13	2.18	0.09	0.07
2014	3.09	2.15	0.09	0.07
2015	3.04	2.12	0.09	0.07
2016	3.00	2.08	0.09	0.07
2017	2.96	2.05	0.09	0.07
2018	2.91	2.02	0.09	0.07
2019	2.86	1.99	0.09	0.07
2020	2.82	1.96	0.09	0.07
2021	2.77	1.93	0.09	0.07
2022	2.73	1.90	0.09	0.07
2023	2.69	1.87	0.09	0.07
2024	2.65	1.84	0.09	0.07
2025	2.61	1.81	0.09	0.07
2026	2.57	1.78	0.09	0.07
2027	2.53	1.76	0.09	0.07
2028	2.49	1.73	0.09	0.07
2029	2.45	1.70	0.09	0.07
2030	2.41	1.68	0.09	0.07

Table C.10. Commercial Other Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	3.61	2.51	0.17	0.14
2005	3.57	2.48	0.17	0.14
2006	3.52	2.45	0.17	0.14
2007	3.48	2.42	0.16	0.13
2008	3.43	2.38	0.16	0.13
2009	3.39	2.35	0.16	0.13
2010	3.34	2.32	0.16	0.13
2011	3.30	2.29	0.16	0.13
2012	3.25	2.26	0.16	0.13
2013	3.21	2.23	0.17	0.14
2014	3.17	2.20	0.17	0.14
2015	3.12	2.17	0.17	0.14
2016	3.08	2.14	0.17	0.14
2017	3.03	2.11	0.17	0.14
2018	2.99	2.08	0.16	0.13
2019	2.94	2.04	0.16	0.13
2020	2.90	2.01	0.16	0.13
2021	2.85	1.98	0.16	0.13
2022	2.81	1.95	0.16	0.13
2023	2.77	1.93	0.16	0.13
2024	2.73	1.90	0.16	0.13
2025	2.69	1.87	0.16	0.13
2026	2.65	1.84	0.16	0.13
2027	2.61	1.81	0.16	0.13
2028	2.57	1.79	0.16	0.13
2029	2.54	1.76	0.16	0.13
2030	2.50	1.74	0.16	0.13

Table C.11. Commercial Warehouse Building Stock Forecast by Building Vintage and Region (billion sq ft)

Year	Existing North	Existing South	New North	New South
2004	6.23	4.33	0.20	0.17
2005	6.17	4.29	0.19	0.15
2006	6.11	4.25	0.18	0.15
2007	6.05	4.20	0.17	0.14
2008	5.99	4.16	0.16	0.13
2009	5.92	4.12	0.16	0.13
2010	5.86	4.07	0.19	0.16
2011	5.79	4.03	0.21	0.17
2012	5.73	3.98	0.22	0.18
2013	5.66	3.93	0.23	0.18
2014	5.59	3.88	0.22	0.18
2015	5.52	3.83	0.21	0.17
2016	5.45	3.78	0.21	0.17
2017	5.37	3.73	0.21	0.17
2018	5.30	3.68	0.21	0.17
2019	5.22	3.63	0.21	0.17
2020	5.15	3.58	0.21	0.17
2021	5.07	3.53	0.21	0.17
2022	5.00	3.48	0.21	0.17
2023	4.93	3.43	0.21	0.17
2024	4.87	3.38	0.21	0.17
2025	4.80	3.33	0.21	0.17
2026	4.73	3.29	0.21	0.17
2027	4.67	3.24	0.21	0.17
2028	4.60	3.20	0.21	0.17
2029	4.54	3.15	0.21	0.17
2030	4.48	3.11	0.21	0.17

C.1.2 Residential Building Stock Forecasts

Table C.12. Residential Mobile Home Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	3.04	3.29	0.12	0.14
2005	2.93	3.18	0.12	0.15
2006	2.83	3.07	0.12	0.15
2007	2.73	2.96	0.12	0.15
2008	2.64	2.85	0.12	0.15
2009	2.54	2.75	0.12	0.14
2010	2.45	2.66	0.11	0.14
2011	2.37	2.57	0.11	0.13
2012	2.29	2.48	0.10	0.12
2013	2.21	2.39	0.09	0.11
2014	2.13	2.31	0.08	0.10
2015	2.05	2.22	0.08	0.10
2016	1.98	2.15	0.08	0.10
2017	1.91	2.07	0.08	0.09
2018	1.85	2.00	0.07	0.09
2019	1.78	1.93	0.07	0.09
2020	1.72	1.86	0.07	0.09
2021	1.71	1.85	0.07	0.09
2022	1.70	1.85	0.07	0.09
2023	1.70	1.84	0.07	0.09
2024	1.69	1.83	0.07	0.09
2025	1.68	1.82	0.07	0.09
2026	1.68	1.82	0.07	0.09
2027	1.67	1.81	0.07	0.09
2028	1.66	1.80	0.07	0.09
2029	1.66	1.80	0.07	0.09
2030	1.65	1.79	0.07	0.09

Table C.13. Residential Multifamily Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	13.37	8.91	0.10	0.10
2005	13.32	8.88	0.10	0.10
2006	13.27	8.84	0.09	0.09
2007	13.21	8.81	0.09	0.09
2008	13.16	8.77	0.10	0.10
2009	13.11	8.74	0.10	0.10
2010	13.05	8.70	0.11	0.11
2011	13.00	8.67	0.11	0.11
2012	12.95	8.63	0.10	0.10
2013	12.90	8.60	0.10	0.10
2014	12.85	8.56	0.10	0.10
2015	12.80	8.53	0.11	0.11
2016	12.74	8.50	0.11	0.11
2017	12.69	8.46	0.12	0.12
2018	12.64	8.43	0.12	0.12
2019	12.59	8.39	0.13	0.13
2020	12.54	8.36	0.13	0.13
2021	12.49	8.33	0.12	0.12
2022	12.44	8.29	0.12	0.12
2023	12.39	8.26	0.12	0.12
2024	12.34	8.23	0.12	0.12
2025	12.29	8.20	0.12	0.12
2026	12.24	8.16	0.12	0.12
2027	12.19	8.13	0.12	0.12
2028	12.15	8.10	0.12	0.12
2029	12.10	8.06	0.12	0.12
2030	12.05	8.03	0.12	0.12

Table C.14. Residential Single-Family Building Stock Forecast by Building Vintage and Region (million households)

Year	Existing North	Existing South	New North	New South
2004	47.41	31.61	0.62	0.62
2005	47.22	31.48	0.63	0.63
2006	47.03	31.35	0.62	0.62
2007	46.84	31.23	0.62	0.62
2008	46.65	31.10	0.62	0.62
2009	46.47	30.98	0.63	0.63
2010	46.28	30.85	0.63	0.63
2011	46.10	30.73	0.64	0.64
2012	45.91	30.61	0.62	0.62
2013	45.73	30.49	0.61	0.61
2014	45.54	30.36	0.61	0.61
2015	45.36	30.24	0.62	0.62
2016	45.18	30.12	0.61	0.61
2017	45.00	30.00	0.62	0.62
2018	44.82	29.88	0.62	0.62
2019	44.64	29.76	0.63	0.63
2020	44.46	29.64	0.62	0.62
2021	44.28	29.52	0.62	0.62
2022	44.11	29.41	0.62	0.62
2023	43.93	29.29	0.62	0.62
2024	43.76	29.17	0.62	0.62
2025	43.58	29.05	0.62	0.62
2026	43.41	28.94	0.62	0.62
2027	43.23	28.82	0.62	0.62
2028	43.06	28.71	0.62	0.62
2029	42.89	28.59	0.62	0.62
2030	42.72	28.48	0.62	0.62

C.2 Baseline Equipment Market Shares

Equipment market shares were broken out by market segment and are estimated from the 1997 "Residential Energy Consumption Survey," the 1995 "Commercial Buildings Energy Consumption Survey," and original PNNL efforts by Dave Belzer. Tables C.15 through C.31 present the baseline equipment market shares by building sector, vintage, and region.

C.2.1 Residential Market Shares

Table C.15. Residential Heating Equipment Market Shares – Existing North

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.12	0.10	0.18	0.01	0.53	0.03	0.02
2005	0.12	0.10	0.18	0.01	0.53	0.03	0.02
2006	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2007	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2008	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2009	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2010	0.12	0.10	0.21	0.01	0.50	0.03	0.02
2011	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2012	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2013	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2014	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2015	0.12	0.10	0.25	0.01	0.46	0.03	0.02
2016	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2017	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2018	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2019	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2020	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2021	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2022	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2023	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2024	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2025	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2026	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2027	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2028	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2029	0.12	0.10	0.28	0.01	0.43	0.03	0.02
2030	0.12	0.10	0.28	0.01	0.43	0.03	0.02

Table C.16. Residential Heating Equipment Market Shares – Existing South

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.21	0.19	0.15	0.00	0.44	0.01	0.00
2005	0.21	0.19	0.15	0.00	0.44	0.01	0.00
2006	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2007	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2008	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2009	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2010	0.21	0.19	0.17	0.00	0.41	0.01	0.00
2011	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2012	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2013	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2014	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2015	0.21	0.19	0.20	0.00	0.38	0.01	0.00
2016	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2017	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2018	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2019	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2020	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2021	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2022	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2023	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2024	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2025	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2026	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2027	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2028	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2029	0.21	0.19	0.23	0.00	0.35	0.01	0.00
2030	0.21	0.19	0.23	0.00	0.35	0.01	0.00

Table C.17. Residential Heating Equipment Market Shares – New North

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.08	0.14	0.17	0.02	0.52	0.03	0.04
2005	0.08	0.14	0.17	0.02	0.52	0.03	0.04
2006	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2007	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2008	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2009	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2010	0.09	0.15	0.20	0.02	0.47	0.03	0.04
2011	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2012	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2013	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2014	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2015	0.10	0.16	0.23	0.02	0.41	0.03	0.04
2016	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2017	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2018	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2019	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2020	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2021	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2022	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2023	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2024	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2025	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2026	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2027	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2028	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2029	0.11	0.17	0.26	0.02	0.36	0.03	0.05
2030	0.11	0.17	0.26	0.02	0.36	0.03	0.05

Table C.18. Residential Heating Equipment Market Shares – New South

Year	Elec FA	Elec HP	Gas HE Furn	Gas HP	Gas Std Furn	Oil Furn	Other
2004	0.13	0.28	0.14	0.00	0.43	0.01	0.01
2005	0.13	0.28	0.14	0.00	0.43	0.01	0.01
2006	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2007	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2008	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2009	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2010	0.15	0.29	0.16	0.00	0.38	0.01	0.01
2011	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2012	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2013	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2014	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2015	0.17	0.30	0.18	0.00	0.32	0.01	0.01
2016	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2017	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2018	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2019	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2020	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2021	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2022	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2023	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2024	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2025	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2026	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2027	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2028	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2029	0.19	0.32	0.20	0.00	0.27	0.01	0.01
2030	0.19	0.32	0.20	0.00	0.27	0.01	0.01

Table C.19. Residential Cooling Equipment Market Shares – Existing North

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.60	0.10	0.03	0.01	0.02	0.24
2005	0.60	0.10	0.03	0.01	0.02	0.24
2006	0.60	0.10	0.03	0.01	0.02	0.24
2007	0.60	0.10	0.03	0.01	0.02	0.24
2008	0.60	0.10	0.03	0.01	0.02	0.24
2009	0.60	0.10	0.03	0.01	0.02	0.24
2010	0.60	0.10	0.03	0.01	0.02	0.24
2011	0.60	0.10	0.03	0.01	0.02	0.24
2012	0.60	0.10	0.03	0.01	0.02	0.24
2013	0.60	0.10	0.03	0.01	0.02	0.24
2014	0.60	0.10	0.03	0.01	0.02	0.24
2015	0.60	0.10	0.03	0.01	0.02	0.24
2016	0.60	0.10	0.03	0.01	0.02	0.24
2017	0.60	0.10	0.03	0.01	0.02	0.24
2018	0.60	0.10	0.03	0.01	0.02	0.24
2019	0.60	0.10	0.03	0.01	0.02	0.24
2020	0.60	0.10	0.03	0.01	0.02	0.24
2021	0.60	0.10	0.03	0.01	0.02	0.24
2022	0.60	0.10	0.03	0.01	0.02	0.24
2023	0.60	0.10	0.03	0.01	0.02	0.24
2024	0.60	0.10	0.03	0.01	0.02	0.24
2025	0.60	0.10	0.03	0.01	0.02	0.24
2026	0.60	0.10	0.03	0.01	0.02	0.24
2027	0.60	0.10	0.03	0.01	0.02	0.24
2028	0.60	0.10	0.03	0.01	0.02	0.24
2029	0.60	0.10	0.03	0.01	0.02	0.24
2030	0.60	0.10	0.03	0.01	0.02	0.24

Table C.20. Residential Cooling Equipment Market Shares – Existing South

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.64	0.19	0.02	0.00	0.00	0.14
2005	0.64	0.19	0.02	0.00	0.00	0.14
2006	0.64	0.19	0.02	0.00	0.00	0.14
2007	0.64	0.19	0.02	0.00	0.00	0.14
2008	0.64	0.19	0.02	0.00	0.00	0.14
2009	0.64	0.19	0.02	0.00	0.00	0.14
2010	0.64	0.19	0.02	0.00	0.00	0.14
2011	0.64	0.19	0.02	0.00	0.00	0.14
2012	0.64	0.19	0.02	0.00	0.00	0.14
2013	0.64	0.19	0.02	0.00	0.00	0.14
2014	0.64	0.19	0.02	0.00	0.00	0.14
2015	0.64	0.19	0.02	0.00	0.00	0.14
2016	0.64	0.19	0.02	0.00	0.00	0.14
2017	0.64	0.19	0.02	0.00	0.00	0.14
2018	0.64	0.19	0.02	0.00	0.00	0.14
2019	0.64	0.19	0.02	0.00	0.00	0.14
2020	0.64	0.19	0.02	0.00	0.00	0.14
2021	0.64	0.19	0.02	0.00	0.00	0.14
2022	0.64	0.19	0.02	0.00	0.00	0.14
2023	0.64	0.19	0.02	0.00	0.00	0.14
2024	0.64	0.19	0.02	0.00	0.00	0.14
2025	0.64	0.19	0.02	0.00	0.00	0.14
2026	0.64	0.19	0.02	0.00	0.00	0.14
2027	0.64	0.19	0.02	0.00	0.00	0.14
2028	0.64	0.19	0.02	0.00	0.00	0.14
2029	0.64	0.19	0.02	0.00	0.00	0.14
2030	0.64	0.19	0.02	0.00	0.00	0.14

Table C.21. Residential Cooling Equipment Market Shares – New North

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.55	0.14	0.03	0.02	0.04	0.22
2005	0.55	0.14	0.03	0.02	0.04	0.22
2006	0.54	0.15	0.02	0.02	0.04	0.22
2007	0.54	0.15	0.02	0.02	0.04	0.22
2008	0.54	0.15	0.02	0.02	0.04	0.22
2009	0.54	0.15	0.02	0.02	0.04	0.22
2010	0.54	0.15	0.02	0.02	0.04	0.22
2011	0.53	0.16	0.02	0.02	0.04	0.22
2012	0.53	0.16	0.02	0.02	0.04	0.22
2013	0.53	0.16	0.02	0.02	0.04	0.22
2014	0.53	0.16	0.02	0.02	0.04	0.22
2015	0.53	0.16	0.02	0.02	0.04	0.22
2016	0.52	0.17	0.02	0.02	0.05	0.22
2017	0.52	0.17	0.02	0.02	0.05	0.22
2018	0.52	0.17	0.02	0.02	0.05	0.22
2019	0.52	0.17	0.02	0.02	0.05	0.22
2020	0.52	0.17	0.02	0.02	0.05	0.22
2021	0.52	0.17	0.02	0.02	0.05	0.22
2022	0.52	0.17	0.02	0.02	0.05	0.22
2023	0.52	0.17	0.02	0.02	0.05	0.22
2024	0.52	0.17	0.02	0.02	0.05	0.22
2025	0.52	0.17	0.02	0.02	0.05	0.22
2026	0.52	0.17	0.02	0.02	0.05	0.22
2027	0.52	0.17	0.02	0.02	0.05	0.22
2028	0.52	0.17	0.02	0.02	0.05	0.22
2029	0.52	0.17	0.02	0.02	0.05	0.22
2030	0.52	0.17	0.02	0.02	0.05	0.22

Table C.22. Residential Cooling Equipment Market Shares – New South

Year	Elec CAC	Elec HP	Elec Room	Gas HP	Other	None
2004	0.57	0.28	0.01	0.00	0.01	0.13
2005	0.57	0.28	0.01	0.00	0.01	0.13
2006	0.55	0.29	0.01	0.00	0.01	0.13
2007	0.55	0.29	0.01	0.00	0.01	0.13
2008	0.55	0.29	0.01	0.00	0.01	0.13
2009	0.55	0.29	0.01	0.00	0.01	0.13
2010	0.55	0.29	0.01	0.00	0.01	0.13
2011	0.54	0.30	0.01	0.00	0.01	0.13
2012	0.54	0.30	0.01	0.00	0.01	0.13
2013	0.54	0.30	0.01	0.00	0.01	0.13
2014	0.54	0.30	0.01	0.00	0.01	0.13
2015	0.54	0.30	0.01	0.00	0.01	0.13
2016	0.53	0.32	0.01	0.00	0.01	0.13
2017	0.53	0.32	0.01	0.00	0.01	0.13
2018	0.53	0.32	0.01	0.00	0.01	0.13
2019	0.53	0.32	0.01	0.00	0.01	0.13
2020	0.53	0.32	0.01	0.00	0.01	0.13
2021	0.53	0.32	0.01	0.00	0.01	0.13
2022	0.53	0.32	0.01	0.00	0.01	0.13
2023	0.53	0.32	0.01	0.00	0.01	0.13
2024	0.53	0.32	0.01	0.00	0.01	0.13
2025	0.53	0.32	0.01	0.00	0.01	0.13
2026	0.53	0.32	0.01	0.00	0.01	0.13
2027	0.53	0.32	0.01	0.00	0.01	0.13
2028	0.53	0.32	0.01	0.00	0.01	0.13
2029	0.53	0.32	0.01	0.00	0.01	0.13
2030	0.53	0.32	0.01	0.00	0.01	0.13

Table C.23. Residential Water Heating Equipment Market Shares – All Building Vintages and Regions

Year	Elec WH	Gas WH	Oil WH
2004	0.23	0.73	0.05
2005	0.23	0.73	0.05
2006	0.22	0.73	0.04
2007	0.22	0.73	0.04
2008	0.22	0.73	0.04
2009	0.22	0.73	0.04
2010	0.22	0.73	0.04
2011	0.22	0.74	0.04
2012	0.22	0.74	0.04
2013	0.22	0.74	0.04
2014	0.22	0.74	0.04
2015	0.22	0.74	0.04
2016	0.22	0.74	0.04
2017	0.22	0.74	0.04
2018	0.22	0.74	0.04
2019	0.22	0.74	0.04
2020	0.22	0.74	0.04
2021	0.22	0.74	0.04
2022	0.22	0.74	0.04
2023	0.22	0.74	0.04
2024	0.22	0.74	0.04
2025	0.22	0.74	0.04
2026	0.22	0.74	0.04
2027	0.22	0.74	0.04
2028	0.22	0.74	0.04
2029	0.22	0.74	0.04
2030	0.22	0.74	0.04

Table C.24. Residential Lighting Equipment Market Shares – All Building Vintages and Regions

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	0.04	0.00	0.00	0.00	0.12	0.85
2005	0.04	0.00	0.00	0.00	0.12	0.85
2006	0.06	0.00	0.00	0.00	0.12	0.82
2007	0.06	0.00	0.00	0.00	0.12	0.82
2008	0.06	0.00	0.00	0.00	0.12	0.82
2009	0.06	0.00	0.00	0.00	0.12	0.82
2010	0.06	0.00	0.00	0.00	0.12	0.82
2011	0.09	0.00	0.00	0.00	0.12	0.80
2012	0.09	0.00	0.00	0.00	0.12	0.80
2013	0.09	0.00	0.00	0.00	0.12	0.80
2014	0.09	0.00	0.00	0.00	0.12	0.80
2015	0.09	0.00	0.00	0.00	0.12	0.80
2016	0.11	0.00	0.00	0.00	0.12	0.77
2017	0.11	0.00	0.00	0.00	0.12	0.77
2018	0.11	0.00	0.00	0.00	0.12	0.77
2019	0.11	0.00	0.00	0.00	0.12	0.77
2020	0.11	0.00	0.00	0.00	0.12	0.77
2021	0.11	0.00	0.00	0.00	0.12	0.77
2022	0.11	0.00	0.00	0.00	0.12	0.77
2023	0.11	0.00	0.00	0.00	0.12	0.77
2024	0.11	0.00	0.00	0.00	0.12	0.77
2025	0.11	0.00	0.00	0.00	0.12	0.77
2026	0.11	0.00	0.00	0.00	0.12	0.77
2027	0.11	0.00	0.00	0.00	0.12	0.77
2028	0.11	0.00	0.00	0.00	0.12	0.77
2029	0.11	0.00	0.00	0.00	0.12	0.77
2030	0.11	0.00	0.00	0.00	0.12	0.77

C.2.2 Commercial Market Shares

Table C.25. Commercial Heating Equipment Market Shares – Existing North

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.08	0.04	0.12	0.36	0.10	0.10	0.20
2005	0.08	0.04	0.12	0.36	0.10	0.10	0.20
2006	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2007	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2008	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2009	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2010	0.08	0.04	0.14	0.33	0.10	0.10	0.20
2011	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2012	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2013	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2014	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2015	0.08	0.04	0.17	0.31	0.10	0.10	0.20
2016	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2017	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2018	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2019	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2020	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2021	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2022	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2023	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2024	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2025	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2026	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2027	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2028	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2029	0.08	0.04	0.19	0.29	0.10	0.10	0.20
2030	0.08	0.04	0.19	0.29	0.10	0.10	0.20

Table C.26. Commercial Heating Equipment Market Shares – Existing South

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.20	0.06	0.10	0.29	0.01	0.04	0.31
2005	0.20	0.06	0.10	0.29	0.01	0.04	0.31
2006	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2007	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2008	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2009	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2010	0.20	0.06	0.12	0.27	0.01	0.04	0.31
2011	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2012	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2013	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2014	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2015	0.20	0.06	0.13	0.25	0.01	0.04	0.31
2016	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2017	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2018	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2019	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2020	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2021	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2022	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2023	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2024	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2025	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2026	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2027	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2028	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2029	0.20	0.06	0.15	0.23	0.01	0.04	0.31
2030	0.20	0.06	0.15	0.23	0.01	0.04	0.31

Table C.27. Commercial Heating Equipment Market Shares – New North

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.14	0.08	0.12	0.36	0.05	0.08	0.19
2005	0.14	0.08	0.12	0.36	0.05	0.08	0.19
2006	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2007	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2008	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2009	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2010	0.14	0.08	0.14	0.33	0.05	0.08	0.19
2011	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2012	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2013	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2014	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2015	0.14	0.08	0.17	0.31	0.05	0.08	0.19
2016	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2017	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2018	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2019	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2020	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2021	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2022	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2023	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2024	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2025	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2026	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2027	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2028	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2029	0.14	0.08	0.19	0.28	0.05	0.08	0.19
2030	0.14	0.08	0.19	0.28	0.05	0.08	0.19

Table C.28. Commercial Heating Equipment Market Shares – New South

Year	Elec FA	Elec HP	Gas HE Furn	Gas Std Furn	Oil Furn	Other	None
2004	0.28	0.09	0.07	0.22	0.00	0.08	0.26
2005	0.28	0.09	0.07	0.22	0.00	0.08	0.26
2006	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2007	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2008	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2009	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2010	0.28	0.09	0.09	0.21	0.00	0.08	0.26
2011	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2012	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2013	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2014	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2015	0.28	0.09	0.10	0.19	0.00	0.08	0.26
2016	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2017	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2018	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2019	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2020	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2021	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2022	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2023	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2024	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2025	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2026	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2027	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2028	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2029	0.28	0.09	0.12	0.18	0.00	0.08	0.26
2030	0.28	0.09	0.12	0.18	0.00	0.08	0.26

Table C.29. Commercial Cooling Equipment Market Shares*

Equipment	Exist North	Exist South	New North	New South
Elec CAC	0.23	0.29	0.34	0.25
Elec Chiller	0.11	0.14	0.11	0.20
Elec HP	0.04	0.06	0.08	0.09
Elec Room	0.05	0.06	0.02	0.11
Gas Chiller	0.01	0.01	0.00	0.00
Other	0.04	0.06	0.04	0.04
None	0.52	0.38	0.41	0.31

*Market shares for commercial cooling are constant throughout the analysis period so are not presented by year.

Table C.30. Commercial Water Heating Equipment Market Shares – All Building Vintages and Regions

Year	Elec WH	Gas WH	Oil WH
2004	0.11	0.83	0.07
2005	0.11	0.83	0.07
2006	0.13	0.82	0.04
2007	0.13	0.82	0.04
2008	0.13	0.82	0.04
2009	0.13	0.82	0.04
2010	0.13	0.82	0.04
2011	0.15	0.81	0.04
2012	0.15	0.81	0.04
2013	0.15	0.81	0.04
2014	0.15	0.81	0.04
2015	0.15	0.81	0.04
2016	0.17	0.79	0.04
2017	0.17	0.79	0.04
2018	0.17	0.79	0.04
2019	0.17	0.79	0.04
2020	0.17	0.79	0.04
2021	0.17	0.79	0.04
2022	0.17	0.79	0.04
2023	0.17	0.79	0.04
2024	0.17	0.79	0.04
2025	0.17	0.79	0.04
2026	0.17	0.79	0.04
2027	0.17	0.79	0.04
2028	0.17	0.79	0.04
2029	0.17	0.79	0.04
2030	0.17	0.79	0.04

Table C.31. Commercial Lighting Equipment Market Shares – All Building Vintages and Regions

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	0.04	0.31	0.12	0.04	0.28	0.22
2005	0.04	0.31	0.12	0.04	0.28	0.22
2006	0.06	0.31	0.12	0.04	0.28	0.19
2007	0.06	0.31	0.12	0.04	0.28	0.19
2008	0.06	0.31	0.12	0.04	0.28	0.19
2009	0.06	0.31	0.12	0.04	0.28	0.19
2010	0.06	0.31	0.12	0.04	0.28	0.19
2011	0.09	0.31	0.12	0.04	0.28	0.17
2012	0.09	0.31	0.12	0.04	0.28	0.17
2013	0.09	0.31	0.12	0.04	0.28	0.17
2014	0.09	0.31	0.12	0.04	0.28	0.17
2015	0.09	0.31	0.12	0.04	0.28	0.17
2016	0.11	0.31	0.12	0.04	0.28	0.14
2017	0.11	0.31	0.12	0.04	0.28	0.14
2018	0.11	0.31	0.12	0.04	0.28	0.14
2019	0.11	0.31	0.12	0.04	0.28	0.14
2020	0.11	0.31	0.12	0.04	0.28	0.14
2021	0.11	0.31	0.12	0.04	0.28	0.14
2022	0.11	0.31	0.12	0.04	0.28	0.14
2023	0.11	0.31	0.12	0.04	0.28	0.14
2024	0.11	0.31	0.12	0.04	0.28	0.14
2025	0.11	0.31	0.12	0.04	0.28	0.14
2026	0.11	0.31	0.12	0.04	0.28	0.14
2027	0.11	0.31	0.12	0.04	0.28	0.14
2028	0.11	0.31	0.12	0.04	0.28	0.14
2029	0.11	0.31	0.12	0.04	0.28	0.14
2030	0.11	0.31	0.12	0.04	0.28	0.14

C.3 Baseline Equipment Efficiencies

The efficiency of equipment stock was developed from EIA's 1995 *Annual Energy Outlook* and input from DOE project managers. Where applicable, the assumed stock efficiency increased to meet equipment standards. Tables C.32 through C.39 present the baseline equipment efficiencies by building sector.

C.3.1 Residential Equipment Efficiencies

Table C.32. Residential Heating Equipment Efficiencies

Year	Elec FA (AFUE)	Elec HP (COP)	Gas HE Furn (AFUE)	Gas HP (COP)	Gas Std Furn (AFUE)	Oil Furn (AFUE)
2004	1.00	2.12	0.92	1.40	0.78	0.80
2005	1.00	2.12	0.92	1.40	0.78	0.81
2006	1.00	2.12	0.92	1.40	0.78	0.81
2007	1.00	2.12	0.92	1.40	0.78	0.81
2008	1.00	2.12	0.92	1.40	0.78	0.81
2009	1.00	2.12	0.92	1.40	0.78	0.81
2010	1.00	2.12	0.92	1.40	0.78	0.81
2011	1.00	2.12	0.92	1.40	0.78	0.82
2012	1.00	2.12	0.92	1.40	0.78	0.82
2013	1.00	2.13	0.92	1.40	0.78	0.82
2014	1.00	2.13	0.92	1.40	0.78	0.82
2015	1.00	2.14	0.92	1.40	0.78	0.82
2016	1.00	2.15	0.92	1.40	0.78	0.82
2017	1.00	2.16	0.92	1.40	0.78	0.82
2018	1.00	2.16	0.92	1.40	0.78	0.82
2019	1.00	2.17	0.92	1.40	0.78	0.82
2020	1.00	2.18	0.92	1.40	0.78	0.82
2021	1.00	2.18	0.92	1.40	0.78	0.82
2022	1.00	2.18	0.92	1.40	0.78	0.82
2023	1.00	2.18	0.92	1.40	0.78	0.82
2024	1.00	2.19	0.92	1.40	0.78	0.82
2025	1.00	2.19	0.92	1.40	0.78	0.82
2026	1.00	2.19	0.92	1.40	0.78	0.82
2027	1.00	2.20	0.92	1.40	0.78	0.82
2028	1.00	2.20	0.92	1.40	0.78	0.82
2029	1.00	2.20	0.92	1.40	0.78	0.82
2030	1.00	2.21	0.92	1.40	0.78	0.82

Table C.33. Residential Cooling Equipment Efficiencies

Year	Elec CAC (COP)	Elec HP (COP)	Elec Room (COP)	Gas HP (COP)
2004	3.13	3.18	2.67	0.95
2005	3.15	3.20	2.70	0.95
2006	3.17	3.21	2.72	0.95
2007	3.18	3.22	2.74	0.95
2008	3.20	3.23	2.76	0.95
2009	3.21	3.24	2.78	0.95
2010	3.22	3.24	2.79	0.95
2011	3.23	3.25	2.80	0.95
2012	3.24	3.25	2.82	0.95
2013	3.25	3.25	2.83	0.95
2014	3.25	3.26	2.84	0.95
2015	3.27	3.26	2.85	0.95
2016	3.29	3.28	2.86	0.95
2017	3.30	3.29	2.86	0.95
2018	3.31	3.31	2.87	0.95
2019	3.32	3.32	2.87	0.95
2020	3.33	3.33	2.87	0.95
2021	3.33	3.33	2.87	0.95
2022	3.33	3.33	2.87	0.95
2023	3.33	3.33	2.87	0.95
2024	3.33	3.33	2.87	0.95
2025	3.33	3.33	2.87	0.95
2026	3.33	3.33	2.87	0.95
2027	3.33	3.33	2.87	0.95
2028	3.33	3.33	2.87	0.95
2029	3.33	3.33	2.87	0.95
2030	3.33	3.33	2.87	0.95

Table C.34. Residential Water Heating Equipment Efficiencies

Year	Elec WH	Gas WH	Oil WH
2004	0.93	0.62	0.55
2005	0.93	0.62	0.55
2006	0.93	0.62	0.56
2007	0.93	0.62	0.56
2008	0.93	0.62	0.56
2009	0.93	0.62	0.56
2010	0.93	0.62	0.56
2011	0.93	0.62	0.56
2012	0.93	0.62	0.56
2013	0.93	0.62	0.56
2014	0.93	0.62	0.56
2015	0.93	0.62	0.56
2016	0.93	0.62	0.56
2017	0.93	0.62	0.56
2018	0.93	0.62	0.56
2019	0.93	0.62	0.56
2020	0.93	0.62	0.56
2021	0.93	0.62	0.56
2022	0.93	0.62	0.56
2023	0.93	0.62	0.56
2024	0.93	0.62	0.56
2025	0.93	0.62	0.56
2026	0.93	0.62	0.56
2027	0.93	0.62	0.56
2028	0.93	0.62	0.56
2029	0.93	0.62	0.56
2030	0.93	0.62	0.56

Table C.35. Residential Lighting Equipment Efficacies (lumens/watt)

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	55	85	22	85	85	15
2005	55	85	22	85	85	15
2006	55	85	22	85	85	15
2007	55	85	22	85	85	15
2008	55	85	22	85	85	15
2009	55	85	22	85	85	15
2010	60	85	22	85	85	15
2011	60	85	22	85	85	15
2012	60	85	22	85	85	15
2013	60	85	22	85	85	15
2014	60	85	22	85	85	15
2015	60	85	22	85	85	15
2016	60	85	22	85	85	15
2017	60	85	22	85	85	15
2018	60	85	22	85	85	15
2019	60	85	22	85	85	15
2020	60	85	22	85	85	15
2021	60	85	22	85	85	15
2022	60	85	22	85	85	15
2023	60	85	22	85	85	15
2024	60	85	22	85	85	15
2025	60	85	22	85	85	15
2026	60	85	22	85	85	15
2027	60	85	22	85	85	15
2028	60	85	22	85	85	15
2029	60	85	22	85	85	15
2030	60	85	22	85	85	15

C.3.2 Commercial Equipment Efficiencies

Table C.36. Commercial Heating Equipment Efficiencies*

Equipment	Efficiency
Elec FA (AFUE)	1.00
Elec HP (COP)	1.99
Gas HE Furn (AFUE)	0.92
Gas Std Furn (AFUE)	0.80
Oil Furn (AFUE)	0.80
*Efficiencies for commercial heating are constant throughout the analysis period so are not presented by year.	

Table C.37. Commercial Cooling Equipment Efficiencies*

Equipment	Efficiency
Elec CAC (COP)	3.02
Elec Chiller (COP)	4.00
Elec HP (COP)	2.93
Elec Room (COP)	2.64
Gas Chiller (COP)	4.00
*Efficiencies for commercial cooling are constant throughout the analysis period so are not presented by year.	

Table C.38. Commercial Water Heating Equipment Efficiencies

Year	Elec WH	Gas WH	Oil WH
2004	0.85	0.80	0.80
2005	0.85	0.80	0.80
2006	0.86	0.80	0.80
2007	0.86	0.80	0.80
2008	0.86	0.80	0.80
2009	0.86	0.80	0.80
2010	0.86	0.80	0.80
2011	0.86	0.80	0.80
2012	0.86	0.80	0.80
2013	0.86	0.80	0.80
2014	0.86	0.80	0.80
2015	0.86	0.80	0.80
2016	0.86	0.80	0.80
2017	0.86	0.80	0.80
2018	0.86	0.80	0.80
2019	0.86	0.80	0.80
2020	0.86	0.80	0.80
2021	0.86	0.80	0.80
2022	0.86	0.80	0.80
2023	0.86	0.80	0.80
2024	0.86	0.80	0.80
2025	0.86	0.80	0.80
2026	0.86	0.80	0.80
2027	0.86	0.80	0.80
2028	0.86	0.80	0.80
2029	0.86	0.80	0.80
2030	0.86	0.80	0.80

Table C.39. Commercial Lighting Equipment Efficacies (lumens/watt)

Year	CFL	EE Fluor	EE Incan	HID	Std Fluor	Std Incan
2004	55	85	22	85	85	15
2005	55	85	22	85	85	15
2006	55	85	22	85	85	15
2007	55	85	22	85	85	15
2008	55	85	22	85	85	15
2009	55	85	22	85	85	15
2010	60	85	22	85	85	15
2011	60	85	22	85	85	15
2012	60	85	22	85	85	15
2013	60	85	22	85	85	15
2014	60	85	22	85	85	15
2015	60	85	22	85	85	15
2016	60	85	22	85	85	15
2017	60	85	22	85	85	15
2018	60	85	22	85	85	15
2019	60	85	22	85	85	15
2020	60	85	22	85	85	15
2021	60	85	22	85	85	15
2022	60	85	22	85	85	15
2023	60	85	22	85	85	15
2024	60	85	22	85	85	15
2025	60	85	22	85	85	15
2026	60	85	22	85	85	15
2027	60	85	22	85	85	15
2028	60	85	22	85	85	15
2029	60	85	22	85	85	15
2030	60	85	22	85	85	15

C.4 Baseline Equipment Life

Equipment life values are used in calculating the number of units representing the potential target market for projects targeting specific pieces of equipment. Baseline factors are taken from *Appliance Magazine*, NEMS, and the *BTS Core Data Book*. Tables C.40 through C.47 present the baseline equipment life assumptions.

C.4.1 Residential Equipment Life

Table C.40. Residential Heating Equipment Life

Equipment	Life (yr)
Elec FA	20
Elec HP	13
Gas HE Furn	20
Gas HP	13
Gas Std Furn	20
Oil Furn	20

Table C.41. Residential Cooling Equipment Life

Equipment	Life (yr)
Elec CAC	11
Elec HP	13
Elec Room	14
Gas HP	13

Table C.42. Residential Water Heating Equipment Life

Equipment	Life (yr)
Elec WH	10
Gas WH	10
Oil WH	10

Table C.43. Residential Lighting Equipment Life

Equipment	Life (yr)
CFL	10
EE Fluor	10
EE Incan	1
HID	13
Std Fluor	10
Std Incan	1

C.4.2 Commercial Equipment Life

Table C.44. Commercial Heating Equipment Life

Equipment	Life (yr)
Elec FA	20
Elec HP	13
Gas HE Furn	20
Gas Std Furn	20
Oil Furn	20

Table C.45. Commercial Cooling Equipment Life

Equipment	Life (yr)
Elec CAC	11
Elec Chiller	20
Elec HP	13
Elec Room	14
Gas Chiller	20

Table C.46. Commercial Water Heating Equipment Life

Equipment	Life (yr)
Elec WH	10
Gas WH	10
Oil WH	10

Table C.47. Commercial Lighting Equipment Life

Equipment	Life (yr)
CFL	10
EE Fluor	10
EE Incan	1
HID	13
Std Fluor	10
Std Incan	1

C.5 End-Use Loads

End-use loads represent the baseline energy use per square foot (commercial) or per unit (residential) for heating, cooling, water heating, and lighting uses. End-use loads were updated in June 2000 with energy use information derived from FEDS to reflect current energy technology and consumption behavior. Tables C.48 through C.61 present the end-use load assumptions by building sector, building type, vintage, and region.

C.5.1 Residential End-Use Loads

Table C.48. Residential Mobile Home End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	10.35	33.45	9.18	29.80	112.53	41.51	92.91	32.96	16.65	14.87	16.65	14.87	1837.50	1837.50	1827.42	1827.42
2005	10.32	33.37	9.16	29.73	112.26	41.41	92.68	32.87	16.61	14.84	16.61	14.84	1832.96	1832.96	1822.90	1822.90
2006	10.30	33.28	9.14	29.65	111.98	41.30	92.45	32.79	16.57	14.80	16.57	14.80	1828.43	1828.43	1818.39	1818.39
2007	10.27	33.20	9.12	29.58	111.70	41.20	92.22	32.71	16.53	14.76	16.53	14.76	1823.91	1823.91	1813.90	1813.90
2008	10.25	33.12	9.09	29.51	111.43	41.10	91.99	32.63	16.49	14.73	16.49	14.73	1819.40	1819.40	1809.41	1809.41
2009	10.22	33.04	9.07	29.43	111.15	41.00	91.77	32.55	16.44	14.69	16.44	14.69	1814.90	1814.90	1804.94	1804.94
2010	10.20	32.96	9.05	29.36	110.88	40.90	91.54	32.47	16.40	14.65	16.40	14.65	1810.42	1810.42	1800.48	1800.48
2011	10.17	32.87	9.03	29.29	110.60	40.80	91.31	32.39	16.36	14.62	16.36	14.62	1805.94	1805.94	1796.03	1796.03
2012	10.15	32.79	9.00	29.21	110.33	40.69	91.09	32.31	16.32	14.58	16.32	14.58	1801.48	1801.48	1791.59	1791.59
2013	10.12	32.71	8.98	29.14	110.06	40.59	90.86	32.23	16.28	14.55	16.28	14.55	1797.03	1797.03	1787.16	1787.16
2014	10.10	32.63	8.96	29.07	109.78	40.49	90.64	32.15	16.24	14.51	16.24	14.51	1792.58	1792.58	1782.74	1782.74
2015	10.07	32.55	8.94	29.00	109.51	40.39	90.41	32.07	16.20	14.47	16.20	14.47	1788.15	1788.15	1778.34	1778.34
2016	10.05	32.47	8.91	28.93	109.24	40.29	90.19	31.99	16.16	14.44	16.16	14.44	1783.73	1783.73	1773.94	1773.94
2017	10.02	32.39	8.89	28.86	108.97	40.19	89.97	31.91	16.12	14.40	16.12	14.40	1779.32	1779.32	1769.56	1769.56
2018	10.00	32.31	8.87	28.78	108.70	40.09	89.75	31.83	16.08	14.37	16.08	14.37	1774.92	1774.92	1765.18	1765.18
2019	9.97	32.23	8.85	28.71	108.43	40.00	89.52	31.75	16.04	14.33	16.04	14.33	1770.54	1770.54	1760.82	1760.82
2020	9.95	32.15	8.83	28.64	108.16	39.90	89.30	31.68	16.00	14.30	16.00	14.30	1766.16	1766.16	1756.46	1756.46
2021	9.92	32.07	8.80	28.57	107.90	39.80	89.08	31.60	15.96	14.26	15.96	14.26	1761.79	1761.79	1752.12	1752.12
2022	9.90	31.99	8.78	28.50	107.63	39.70	88.86	31.52	15.92	14.23	15.92	14.23	1757.44	1757.44	1747.79	1747.79
2023	9.87	31.91	8.76	28.43	107.36	39.60	88.64	31.44	15.88	14.19	15.88	14.19	1753.09	1753.09	1743.47	1743.47
2024	9.85	31.83	8.74	28.36	107.10	39.50	88.42	31.36	15.85	14.16	15.85	14.16	1748.76	1748.76	1739.16	1739.16
2025	9.82	31.75	8.72	28.29	106.83	39.41	88.20	31.29	15.81	14.12	15.81	14.12	1744.44	1744.44	1734.86	1734.86
2026	9.80	31.68	8.70	28.22	106.57	39.31	87.99	31.21	15.77	14.09	15.77	14.09	1740.13	1740.13	1730.57	1730.57
2027	9.78	31.60	8.67	28.15	106.31	39.21	87.77	31.13	15.73	14.05	15.73	14.05	1735.82	1735.82	1726.30	1726.30
2028	9.75	31.52	8.65	28.08	106.04	39.11	87.55	31.05	15.69	14.02	15.69	14.02	1731.53	1731.53	1722.03	1722.03
2029	9.73	31.44	8.63	28.01	105.78	39.02	87.33	30.98	15.65	13.98	15.65	13.98	1727.25	1727.25	1717.77	1717.77
2030	9.70	31.36	8.61	27.94	105.52	38.92	87.12	30.90	15.61	13.95	15.61	13.95	1722.98	1722.98	1713.53	1713.53

Table C.49. Residential Multifamily End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	9.52	24.16	9.57	23.91	20.12	4.64	16.30	3.39	16.76	14.36	16.76	14.36	2312.70	2312.70	2304.61	2304.61
2005	9.50	24.10	9.55	23.85	20.07	4.62	16.26	3.38	16.72	14.32	16.72	14.32	2306.99	2306.99	2298.91	2298.91
2006	9.48	24.04	9.53	23.80	20.02	4.61	16.22	3.37	16.68	14.29	16.68	14.29	2301.28	2301.28	2293.23	2293.23
2007	9.45	23.98	9.50	23.74	19.97	4.60	16.18	3.36	16.64	14.25	16.64	14.25	2295.60	2295.60	2287.56	2287.56
2008	9.43	23.92	9.48	23.68	19.92	4.59	16.14	3.36	16.60	14.22	16.60	14.22	2289.92	2289.92	2281.90	2281.90
2009	9.41	23.86	9.46	23.62	19.87	4.58	16.10	3.35	16.55	14.18	16.55	14.18	2284.26	2284.26	2276.26	2276.26
2010	9.38	23.80	9.43	23.56	19.82	4.57	16.06	3.34	16.51	14.15	16.51	14.15	2278.61	2278.61	2270.64	2270.64
2011	9.36	23.74	9.41	23.50	19.77	4.56	16.02	3.33	16.47	14.11	16.47	14.11	2272.98	2272.98	2265.02	2265.02
2012	9.34	23.68	9.39	23.44	19.72	4.54	15.98	3.32	16.43	14.08	16.43	14.08	2267.36	2267.36	2259.43	2259.43
2013	9.31	23.62	9.36	23.39	19.67	4.53	15.94	3.31	16.39	14.04	16.39	14.04	2261.76	2261.76	2253.84	2253.84
2014	9.29	23.57	9.34	23.33	19.62	4.52	15.91	3.31	16.35	14.01	16.35	14.01	2256.17	2256.17	2248.27	2248.27
2015	9.27	23.51	9.32	23.27	19.57	4.51	15.87	3.30	16.31	13.97	16.31	13.97	2250.59	2250.59	2242.71	2242.71
2016	9.24	23.45	9.29	23.21	19.53	4.50	15.83	3.29	16.27	13.94	16.27	13.94	2245.03	2245.03	2237.17	2237.17
2017	9.22	23.39	9.27	23.16	19.48	4.49	15.79	3.28	16.23	13.90	16.23	13.90	2239.48	2239.48	2231.64	2231.64
2018	9.20	23.33	9.25	23.10	19.43	4.48	15.75	3.27	16.19	13.87	16.19	13.87	2233.94	2233.94	2226.12	2226.12
2019	9.18	23.28	9.22	23.04	19.38	4.47	15.71	3.27	16.15	13.84	16.15	13.84	2228.42	2228.42	2220.62	2220.62
2020	9.15	23.22	9.20	22.99	19.33	4.46	15.67	3.26	16.11	13.80	16.11	13.80	2222.91	2222.91	2215.13	2215.13
2021	9.13	23.16	9.18	22.93	19.29	4.44	15.63	3.25	16.07	13.77	16.07	13.77	2217.42	2217.42	2209.65	2209.65
2022	9.11	23.10	9.16	22.87	19.24	4.43	15.59	3.24	16.03	13.73	16.03	13.73	2211.93	2211.93	2204.19	2204.19
2023	9.09	23.05	9.13	22.82	19.19	4.42	15.55	3.23	15.99	13.70	15.99	13.70	2206.47	2206.47	2198.74	2198.74
2024	9.06	22.99	9.11	22.76	19.14	4.41	15.52	3.22	15.95	13.67	15.95	13.67	2201.01	2201.01	2193.31	2193.31
2025	9.04	22.93	9.09	22.70	19.10	4.40	15.48	3.22	15.91	13.63	15.91	13.63	2195.57	2195.57	2187.88	2187.88
2026	9.02	22.88	9.07	22.65	19.05	4.39	15.44	3.21	15.87	13.60	15.87	13.60	2190.14	2190.14	2182.48	2182.48
2027	9.00	22.82	9.04	22.59	19.00	4.38	15.40	3.20	15.83	13.56	15.83	13.56	2184.73	2184.73	2177.08	2177.08
2028	8.97	22.76	9.02	22.53	18.96	4.37	15.36	3.19	15.79	13.53	15.79	13.53	2179.33	2179.33	2171.70	2171.70
2029	8.95	22.71	9.00	22.48	18.91	4.36	15.33	3.19	15.75	13.50	15.75	13.50	2173.94	2173.94	2166.33	2166.33
2030	8.93	22.65	8.98	22.42	18.86	4.35	15.29	3.18	15.72	13.46	15.72	13.46	2168.57	2168.57	2160.98	2160.98

Table C.50. Residential Single-Family End-Use Loads

Year	Cool (MMBtu/HH)				Heat (MMBtu/HH)				Water Heat (MMBtu/HH)				Light (kWh/HH)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	10.23	33.37	9.77	30.89	67.87	18.17	49.86	11.58	21.93	19.32	21.93	19.32	2882.98	2882.98	2867.15	2867.15
2005	10.21	33.29	9.74	30.81	67.70	18.13	49.73	11.55	21.88	19.27	21.88	19.27	2875.85	2875.85	2860.06	2860.06
2006	10.18	33.20	9.72	30.74	67.54	18.08	49.61	11.52	21.82	19.23	21.82	19.23	2868.74	2868.74	2852.99	2852.99
2007	10.16	33.12	9.70	30.66	67.37	18.04	49.49	11.49	21.77	19.18	21.77	19.18	2861.65	2861.65	2845.94	2845.94
2008	10.13	33.04	9.67	30.59	67.20	17.99	49.36	11.46	21.72	19.13	21.72	19.13	2854.58	2854.58	2838.91	2838.91
2009	10.11	32.96	9.65	30.51	67.04	17.95	49.24	11.43	21.66	19.08	21.66	19.08	2847.52	2847.52	2831.89	2831.89
2010	10.08	32.88	9.62	30.43	66.87	17.91	49.12	11.41	21.61	19.04	21.61	19.04	2840.48	2840.48	2824.89	2824.89
2011	10.06	32.80	9.60	30.36	66.70	17.86	49.00	11.38	21.55	18.99	21.55	18.99	2833.46	2833.46	2817.90	2817.90
2012	10.03	32.71	9.58	30.28	66.54	17.82	48.88	11.35	21.50	18.94	21.50	18.94	2826.45	2826.45	2810.94	2810.94
2013	10.01	32.63	9.55	30.21	66.38	17.77	48.76	11.32	21.45	18.90	21.45	18.90	2819.47	2819.47	2803.99	2803.99
2014	9.98	32.55	9.53	30.13	66.21	17.73	48.64	11.29	21.39	18.85	21.39	18.85	2812.50	2812.50	2797.06	2797.06
2015	9.96	32.47	9.51	30.06	66.05	17.69	48.52	11.27	21.34	18.80	21.34	18.80	2805.55	2805.55	2790.14	2790.14
2016	9.94	32.39	9.48	29.99	65.88	17.64	48.40	11.24	21.29	18.76	21.29	18.76	2798.61	2798.61	2783.25	2783.25
2017	9.91	32.31	9.46	29.91	65.72	17.60	48.28	11.21	21.24	18.71	21.24	18.71	2791.69	2791.69	2776.37	2776.37
2018	9.89	32.23	9.44	29.84	65.56	17.55	48.16	11.18	21.18	18.66	21.18	18.66	2784.79	2784.79	2769.50	2769.50
2019	9.86	32.15	9.41	29.76	65.40	17.51	48.04	11.16	21.13	18.62	21.13	18.62	2777.91	2777.91	2762.66	2762.66
2020	9.84	32.07	9.39	29.69	65.24	17.47	47.92	11.13	21.08	18.57	21.08	18.57	2771.04	2771.04	2755.83	2755.83
2021	9.81	31.99	9.37	29.62	65.07	17.42	47.80	11.10	21.03	18.53	21.03	18.53	2764.19	2764.19	2749.02	2749.02
2022	9.79	31.92	9.34	29.54	64.91	17.38	47.68	11.07	20.98	18.48	20.98	18.48	2757.36	2757.36	2742.22	2742.22
2023	9.76	31.84	9.32	29.47	64.75	17.34	47.57	11.05	20.92	18.43	20.92	18.43	2750.54	2750.54	2735.44	2735.44
2024	9.74	31.76	9.30	29.40	64.59	17.30	47.45	11.02	20.87	18.39	20.87	18.39	2743.74	2743.74	2728.68	2728.68
2025	9.72	31.68	9.27	29.33	64.43	17.25	47.33	10.99	20.82	18.34	20.82	18.34	2736.96	2736.96	2721.94	2721.94
2026	9.69	31.60	9.25	29.25	64.27	17.21	47.21	10.96	20.77	18.30	20.77	18.30	2730.19	2730.19	2715.21	2715.21
2027	9.67	31.52	9.23	29.18	64.11	17.17	47.10	10.94	20.72	18.25	20.72	18.25	2723.45	2723.45	2708.50	2708.50
2028	9.64	31.44	9.21	29.11	63.96	17.13	46.98	10.91	20.67	18.21	20.67	18.21	2716.71	2716.71	2701.80	2701.80
2029	9.62	31.37	9.18	29.04	63.80	17.08	46.86	10.88	20.62	18.16	20.62	18.16	2710.00	2710.00	2695.12	2695.12
2030	9.60	31.29	9.16	28.96	63.64	17.04	46.75	10.86	20.56	18.12	20.56	18.12	2703.30	2703.30	2688.46	2688.46

C.5.2 Commercial End-Use Loads

Table C.51. Commercial Assembly End-Use Loads

	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (Kbtu/SF)				Light (KWh/SF)			
Year	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	14.93	33.65	14.45	31.21	23.35	9.16	15.93	5.46	1.82	1.69	1.87	1.72	4.91	4.81	4.89	4.75
2005	14.89	33.57	14.42	31.13	23.30	9.14	15.90	5.44	1.82	1.68	1.86	1.72	4.90	4.80	4.88	4.74
2006	14.85	33.48	14.38	31.06	23.24	9.12	15.86	5.43	1.81	1.68	1.86	1.72	4.89	4.78	4.87	4.73
2007	14.82	33.40	14.35	30.98	23.18	9.09	15.82	5.41	1.81	1.68	1.85	1.71	4.87	4.77	4.86	4.72
2008	14.78	33.32	14.31	30.90	23.12	9.07	15.78	5.40	1.80	1.67	1.85	1.71	4.86	4.76	4.85	4.71
2009	14.74	33.24	14.28	30.83	23.07	9.05	15.74	5.39	1.80	1.67	1.84	1.70	4.85	4.75	4.83	4.70
2010	14.71	33.15	14.24	30.75	23.01	9.03	15.70	5.37	1.80	1.66	1.84	1.70	4.84	4.74	4.82	4.68
2011	14.67	33.07	14.21	30.67	22.95	9.00	15.66	5.36	1.79	1.66	1.83	1.69	4.83	4.73	4.81	4.67
2012	14.63	32.99	14.17	30.60	22.90	8.98	15.62	5.35	1.79	1.66	1.83	1.69	4.81	4.71	4.80	4.66
2013	14.60	32.91	14.14	30.52	22.84	8.96	15.58	5.34	1.78	1.65	1.82	1.69	4.80	4.70	4.79	4.65
2014	14.56	32.83	14.10	30.45	22.78	8.94	15.55	5.32	1.78	1.65	1.82	1.68	4.79	4.69	4.77	4.64
2015	14.52	32.75	14.07	30.37	22.73	8.91	15.51	5.31	1.77	1.64	1.82	1.68	4.78	4.68	4.76	4.63
2016	14.49	32.67	14.03	30.30	22.67	8.89	15.47	5.30	1.77	1.64	1.81	1.67	4.77	4.67	4.75	4.62
2017	14.45	32.59	14.00	30.22	22.61	8.87	15.43	5.28	1.77	1.63	1.81	1.67	4.75	4.66	4.74	4.60
2018	14.42	32.50	13.96	30.15	22.56	8.85	15.39	5.27	1.76	1.63	1.80	1.67	4.74	4.64	4.73	4.59
2019	14.38	32.42	13.93	30.07	22.50	8.83	15.35	5.26	1.76	1.63	1.80	1.66	4.73	4.63	4.72	4.58
2020	14.35	32.34	13.89	30.00	22.45	8.80	15.32	5.24	1.75	1.62	1.79	1.66	4.72	4.62	4.70	4.57
2021	14.31	32.26	13.86	29.92	22.39	8.78	15.28	5.23	1.75	1.62	1.79	1.65	4.71	4.61	4.69	4.56
2022	14.28	32.18	13.82	29.85	22.34	8.76	15.24	5.22	1.74	1.61	1.78	1.65	4.70	4.60	4.68	4.55
2023	14.24	32.11	13.79	29.78	22.28	8.74	15.20	5.20	1.74	1.61	1.78	1.65	4.68	4.59	4.67	4.54
2024	14.20	32.03	13.76	29.70	22.23	8.72	15.17	5.19	1.73	1.61	1.78	1.64	4.67	4.58	4.66	4.53
2025	14.17	31.95	13.72	29.63	22.17	8.70	15.13	5.18	1.73	1.60	1.77	1.64	4.66	4.56	4.65	4.51
2026	14.13	31.87	13.69	29.56	22.12	8.67	15.09	5.17	1.73	1.60	1.77	1.63	4.65	4.55	4.63	4.50
2027	14.10	31.79	13.65	29.48	22.06	8.65	15.05	5.15	1.72	1.59	1.76	1.63	4.64	4.54	4.62	4.49
2028	14.06	31.71	13.62	29.41	22.01	8.63	15.02	5.14	1.72	1.59	1.76	1.62	4.63	4.53	4.61	4.48
2029	14.03	31.63	13.59	29.34	21.95	8.61	14.98	5.13	1.71	1.59	1.75	1.62	4.62	4.52	4.60	4.47
2030	14.00	31.55	13.55	29.26	21.90	8.59	14.94	5.12	1.71	1.58	1.75	1.62	4.60	4.51	4.59	4.46

Table C.52. Commercial Education End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	14.68	32.28	13.53	29.01	26.98	9.55	18.76	7.16	3.52	3.09	3.54	3.12	3.74	3.75	3.34	3.36
2005	14.64	32.20	13.49	28.94	26.91	9.53	18.71	7.14	3.51	3.09	3.53	3.12	3.73	3.74	3.33	3.35
2006	14.61	32.12	13.46	28.87	26.84	9.50	18.67	7.12	3.50	3.08	3.52	3.11	3.72	3.73	3.33	3.34
2007	14.57	32.04	13.43	28.80	26.78	9.48	18.62	7.11	3.49	3.07	3.51	3.10	3.71	3.73	3.32	3.33
2008	14.54	31.96	13.39	28.73	26.71	9.46	18.57	7.09	3.48	3.06	3.50	3.09	3.71	3.72	3.31	3.33
2009	14.50	31.88	13.36	28.66	26.64	9.43	18.53	7.07	3.47	3.06	3.50	3.09	3.70	3.71	3.30	3.32
2010	14.46	31.80	13.33	28.59	26.58	9.41	18.48	7.05	3.46	3.05	3.49	3.08	3.69	3.70	3.29	3.31
2011	14.43	31.72	13.30	28.52	26.51	9.39	18.44	7.04	3.46	3.04	3.48	3.07	3.68	3.69	3.29	3.30
2012	14.39	31.64	13.26	28.45	26.45	9.36	18.39	7.02	3.45	3.03	3.47	3.06	3.67	3.68	3.28	3.29
2013	14.36	31.56	13.23	28.38	26.38	9.34	18.35	7.00	3.44	3.03	3.46	3.06	3.66	3.67	3.27	3.29
2014	14.32	31.49	13.20	28.31	26.32	9.32	18.30	6.98	3.43	3.02	3.45	3.05	3.65	3.66	3.26	3.28
2015	14.29	31.41	13.16	28.24	26.25	9.29	18.26	6.97	3.42	3.01	3.44	3.04	3.64	3.65	3.25	3.27
2016	14.25	31.33	13.13	28.17	26.19	9.27	18.21	6.95	3.41	3.00	3.44	3.03	3.63	3.64	3.24	3.26
2017	14.22	31.25	13.10	28.10	26.12	9.25	18.17	6.93	3.40	3.00	3.43	3.03	3.62	3.63	3.24	3.25
2018	14.18	31.18	13.07	28.03	26.06	9.22	18.12	6.91	3.40	2.99	3.42	3.02	3.61	3.63	3.23	3.25
2019	14.14	31.10	13.03	27.96	25.99	9.20	18.08	6.90	3.39	2.98	3.41	3.01	3.61	3.62	3.22	3.24
2020	14.11	31.02	13.00	27.89	25.93	9.18	18.03	6.88	3.38	2.97	3.40	3.00	3.60	3.61	3.21	3.23
2021	14.08	30.95	12.97	27.82	25.86	9.16	17.99	6.86	3.37	2.97	3.39	3.00	3.59	3.60	3.20	3.22
2022	14.04	30.87	12.94	27.75	25.80	9.13	17.94	6.85	3.36	2.96	3.39	2.99	3.58	3.59	3.20	3.21
2023	14.01	30.79	12.91	27.68	25.74	9.11	17.90	6.83	3.35	2.95	3.38	2.98	3.57	3.58	3.19	3.21
2024	13.97	30.72	12.87	27.61	25.67	9.09	17.85	6.81	3.35	2.95	3.37	2.97	3.56	3.57	3.18	3.20
2025	13.94	30.64	12.84	27.54	25.61	9.07	17.81	6.80	3.34	2.94	3.36	2.97	3.55	3.56	3.17	3.19
2026	13.90	30.57	12.81	27.48	25.55	9.04	17.77	6.78	3.33	2.93	3.35	2.96	3.54	3.55	3.17	3.18
2027	13.87	30.49	12.78	27.41	25.48	9.02	17.72	6.76	3.32	2.92	3.34	2.95	3.54	3.55	3.16	3.17
2028	13.83	30.41	12.75	27.34	25.42	9.00	17.68	6.75	3.31	2.92	3.34	2.94	3.53	3.54	3.15	3.17
2029	13.80	30.34	12.72	27.27	25.36	8.98	17.63	6.73	3.30	2.91	3.33	2.94	3.52	3.53	3.14	3.16
2030	13.77	30.26	12.68	27.21	25.29	8.95	17.59	6.71	3.30	2.90	3.32	2.93	3.51	3.52	3.13	3.15

Table C.53. Commercial Food Sales End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	38.85	78.59	40.11	75.47	21.68	4.21	10.74	1.36	4.05	4.68	4.13	10.04	12.80	12.80	11.92	11.92
2005	38.75	78.40	40.01	75.28	21.63	4.20	10.71	1.36	4.04	4.67	4.12	10.02	12.77	12.77	11.89	11.89
2006	38.65	78.20	39.91	75.09	21.57	4.19	10.69	1.35	4.03	4.66	4.11	9.99	12.74	12.74	11.86	11.86
2007	38.56	78.01	39.81	74.91	21.52	4.18	10.66	1.35	4.02	4.64	4.10	9.97	12.71	12.71	11.83	11.83
2008	38.46	77.82	39.71	74.72	21.47	4.17	10.63	1.35	4.01	4.63	4.09	9.94	12.68	12.68	11.80	11.80
2009	38.37	77.63	39.62	74.54	21.41	4.16	10.61	1.34	4.00	4.62	4.08	9.92	12.64	12.65	11.77	11.77
2010	38.27	77.43	39.52	74.35	21.36	4.15	10.58	1.34	3.99	4.61	4.07	9.90	12.61	12.61	11.74	11.74
2011	38.18	77.24	39.42	74.17	21.31	4.14	10.55	1.34	3.98	4.60	4.06	9.87	12.58	12.58	11.71	11.71
2012	38.08	77.05	39.32	73.99	21.25	4.13	10.53	1.33	3.97	4.59	4.05	9.85	12.55	12.55	11.69	11.69
2013	37.99	76.86	39.23	73.80	21.20	4.12	10.50	1.33	3.96	4.58	4.04	9.82	12.52	12.52	11.66	11.66
2014	37.90	76.67	39.13	73.62	21.15	4.11	10.48	1.33	3.95	4.56	4.03	9.80	12.49	12.49	11.63	11.63
2015	37.80	76.48	39.03	73.44	21.10	4.10	10.45	1.32	3.94	4.55	4.02	9.77	12.46	12.46	11.60	11.60
2016	37.71	76.29	38.94	73.26	21.05	4.09	10.43	1.32	3.93	4.54	4.01	9.75	12.43	12.43	11.57	11.57
2017	37.62	76.10	38.84	73.08	20.99	4.08	10.40	1.32	3.92	4.53	4.00	9.73	12.40	12.40	11.54	11.54
2018	37.52	75.92	38.74	72.90	20.94	4.07	10.37	1.31	3.91	4.52	3.99	9.70	12.37	12.37	11.51	11.51
2019	37.43	75.73	38.65	72.72	20.89	4.06	10.35	1.31	3.90	4.51	3.98	9.68	12.34	12.34	11.49	11.49
2020	37.34	75.54	38.55	72.54	20.84	4.05	10.32	1.31	3.89	4.50	3.97	9.65	12.30	12.31	11.46	11.46
2021	37.25	75.35	38.46	72.36	20.79	4.04	10.30	1.30	3.88	4.49	3.96	9.63	12.27	12.28	11.43	11.43
2022	37.15	75.17	38.36	72.18	20.73	4.03	10.27	1.30	3.87	4.47	3.95	9.61	12.24	12.25	11.40	11.40
2023	37.06	74.98	38.27	72.00	20.68	4.02	10.25	1.30	3.86	4.46	3.94	9.58	12.21	12.22	11.37	11.37
2024	36.97	74.80	38.17	71.82	20.63	4.01	10.22	1.29	3.85	4.45	3.93	9.56	12.18	12.19	11.34	11.34
2025	36.88	74.61	38.08	71.64	20.58	4.00	10.20	1.29	3.84	4.44	3.92	9.53	12.15	12.16	11.32	11.32
2026	36.79	74.43	37.98	71.47	20.53	3.99	10.17	1.29	3.83	4.43	3.91	9.51	12.12	12.13	11.29	11.29
2027	36.70	74.24	37.89	71.29	20.48	3.98	10.15	1.28	3.82	4.42	3.90	9.49	12.09	12.10	11.26	11.26
2028	36.61	74.06	37.80	71.11	20.43	3.97	10.12	1.28	3.81	4.41	3.89	9.46	12.06	12.07	11.23	11.23
2029	36.52	73.88	37.70	70.94	20.38	3.96	10.09	1.28	3.80	4.40	3.88	9.44	12.03	12.04	11.20	11.20
2030	36.43	73.69	37.61	70.76	20.33	3.95	10.07	1.28	3.80	4.39	3.87	9.42	12.00	12.01	11.18	11.18

Table C.54. Commercial Food Service End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	47.51	93.35	51.34	91.38	22.03	6.07	8.17	2.52	10.02	9.05	10.08	9.10	9.29	9.29	9.29	9.29
2005	47.39	93.12	51.22	91.15	21.97	6.05	8.15	2.51	9.99	9.03	10.05	9.08	9.27	9.27	9.27	9.27
2006	47.28	92.89	51.09	90.92	21.92	6.04	8.13	2.51	9.97	9.01	10.03	9.06	9.24	9.24	9.24	9.24
2007	47.16	92.66	50.96	90.70	21.86	6.02	8.11	2.50	9.94	8.99	10.00	9.04	9.22	9.22	9.22	9.22
2008	47.04	92.43	50.84	90.48	21.81	6.01	8.09	2.50	9.92	8.96	9.98	9.01	9.20	9.20	9.20	9.20
2009	46.93	92.20	50.71	90.25	21.76	5.99	8.07	2.49	9.90	8.94	9.95	8.99	9.18	9.18	9.18	9.18
2010	46.81	91.97	50.59	90.03	21.70	5.98	8.05	2.48	9.87	8.92	9.93	8.97	9.15	9.15	9.15	9.15
2011	46.69	91.75	50.46	89.81	21.65	5.96	8.03	2.48	9.85	8.90	9.90	8.95	9.13	9.13	9.13	9.13
2012	46.58	91.52	50.34	89.58	21.59	5.95	8.01	2.47	9.82	8.88	9.88	8.92	9.11	9.11	9.11	9.11
2013	46.46	91.29	50.21	89.36	21.54	5.93	7.99	2.46	9.80	8.85	9.86	8.90	9.09	9.09	9.09	9.09
2014	46.35	91.07	50.09	89.14	21.49	5.92	7.97	2.46	9.77	8.83	9.83	8.88	9.06	9.06	9.06	9.06
2015	46.23	90.84	49.96	88.92	21.43	5.90	7.95	2.45	9.75	8.81	9.81	8.86	9.04	9.04	9.04	9.04
2016	46.12	90.62	49.84	88.70	21.38	5.89	7.93	2.45	9.73	8.79	9.78	8.84	9.02	9.02	9.02	9.02
2017	46.01	90.39	49.72	88.48	21.33	5.87	7.91	2.44	9.70	8.77	9.76	8.81	9.00	9.00	9.00	9.00
2018	45.89	90.17	49.59	88.26	21.28	5.86	7.89	2.43	9.68	8.75	9.73	8.79	8.97	8.97	8.97	8.97
2019	45.78	89.95	49.47	88.05	21.22	5.85	7.87	2.43	9.65	8.72	9.71	8.77	8.95	8.95	8.95	8.95
2020	45.67	89.72	49.35	87.83	21.17	5.83	7.85	2.42	9.63	8.70	9.69	8.75	8.93	8.93	8.93	8.93
2021	45.55	89.50	49.23	87.61	21.12	5.82	7.83	2.42	9.61	8.68	9.66	8.73	8.91	8.91	8.91	8.91
2022	45.44	89.28	49.11	87.39	21.07	5.80	7.81	2.41	9.58	8.66	9.64	8.71	8.89	8.89	8.89	8.89
2023	45.33	89.06	48.98	87.18	21.01	5.79	7.79	2.40	9.56	8.64	9.62	8.68	8.86	8.86	8.86	8.86
2024	45.22	88.84	48.86	86.96	20.96	5.77	7.77	2.40	9.53	8.62	9.59	8.66	8.84	8.84	8.84	8.84
2025	45.10	88.62	48.74	86.75	20.91	5.76	7.75	2.39	9.51	8.60	9.57	8.64	8.82	8.82	8.82	8.82
2026	44.99	88.40	48.62	86.53	20.86	5.74	7.73	2.39	9.49	8.57	9.54	8.62	8.80	8.80	8.80	8.80
2027	44.88	88.18	48.50	86.32	20.81	5.73	7.71	2.38	9.46	8.55	9.52	8.60	8.78	8.78	8.78	8.78
2028	44.77	87.97	48.38	86.11	20.76	5.72	7.70	2.37	9.44	8.53	9.50	8.58	8.75	8.75	8.75	8.75
2029	44.66	87.75	48.26	85.89	20.70	5.70	7.68	2.37	9.42	8.51	9.47	8.56	8.73	8.73	8.73	8.73
2030	44.55	87.53	48.14	85.68	20.65	5.69	7.66	2.36	0.00	0.00	0.00	0.00	8.71	8.71	8.71	8.71

Table C.55. Commercial Health Care End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	45.20	92.71	41.25	87.40	8.47	2.94	6.91	1.08	34.09	31.13	34.58	31.54	14.57	14.51	13.01	12.94
2005	45.09	92.48	41.14	87.19	8.45	2.94	6.90	1.08	34.01	31.05	34.49	31.47	14.53	14.48	12.98	12.91
2006	44.98	92.25	41.04	86.97	8.43	2.93	6.88	1.08	33.93	30.97	34.41	31.39	14.49	14.44	12.94	12.88
2007	44.86	92.03	40.94	86.76	8.41	2.92	6.86	1.08	33.84	30.90	34.32	31.31	14.46	14.41	12.91	12.85
2008	44.75	91.80	40.84	86.54	8.39	2.91	6.85	1.07	33.76	30.82	34.24	31.23	14.42	14.37	12.88	12.81
2009	44.64	91.57	40.74	86.33	8.37	2.91	6.83	1.07	33.68	30.74	34.15	31.16	14.39	14.34	12.85	12.78
2010	44.53	91.35	40.64	86.11	8.35	2.90	6.81	1.07	33.59	30.67	34.07	31.08	14.35	14.30	12.82	12.75
2011	44.42	91.12	40.54	85.90	8.33	2.89	6.80	1.07	33.51	30.59	33.98	31.00	14.31	14.26	12.79	12.72
2012	44.31	90.89	40.44	85.69	8.30	2.89	6.78	1.06	33.43	30.52	33.90	30.93	14.28	14.23	12.75	12.69
2013	44.20	90.67	40.34	85.48	8.28	2.88	6.76	1.06	33.34	30.44	33.82	30.85	14.24	14.19	12.72	12.66
2014	44.09	90.45	40.24	85.27	8.26	2.87	6.75	1.06	33.26	30.37	33.73	30.77	14.21	14.16	12.69	12.63
2015	43.98	90.22	40.14	85.06	8.24	2.86	6.73	1.06	33.18	30.29	33.65	30.70	14.17	14.12	12.66	12.59
2016	43.88	90.00	40.04	84.84	8.22	2.86	6.71	1.05	33.10	30.22	33.57	30.62	14.14	14.09	12.63	12.56
2017	43.77	89.78	39.94	84.64	8.20	2.85	6.70	1.05	33.02	30.14	33.48	30.55	14.10	14.05	12.60	12.53
2018	43.66	89.55	39.84	84.43	8.18	2.84	6.68	1.05	32.93	30.07	33.40	30.47	14.07	14.02	12.57	12.50
2019	43.55	89.33	39.74	84.22	8.16	2.84	6.66	1.05	32.85	29.99	33.32	30.40	14.03	13.99	12.53	12.47
2020	43.44	89.11	39.64	84.01	8.14	2.83	6.65	1.04	32.77	29.92	33.24	30.32	14.00	13.95	12.50	12.44
2021	43.34	88.89	39.55	83.80	8.12	2.82	6.63	1.04	32.69	29.85	33.15	30.25	13.96	13.92	12.47	12.41
2022	43.23	88.67	39.45	83.59	8.10	2.82	6.61	1.04	32.61	29.77	33.07	30.17	13.93	13.88	12.44	12.38
2023	43.12	88.45	39.35	83.39	8.08	2.81	6.60	1.03	32.53	29.70	32.99	30.10	13.90	13.85	12.41	12.35
2024	43.02	88.23	39.25	83.18	8.06	2.80	6.58	1.03	32.45	29.62	32.91	30.02	13.86	13.81	12.38	12.32
2025	42.91	88.02	39.16	82.98	8.04	2.79	6.56	1.03	32.37	29.55	32.83	29.95	13.83	13.78	12.35	12.29
2026	42.80	87.80	39.06	82.77	8.02	2.79	6.55	1.03	32.29	29.48	32.75	29.87	13.79	13.75	12.32	12.26
2027	42.70	87.58	38.96	82.57	8.00	2.78	6.53	1.02	32.21	29.41	32.66	29.80	13.76	13.71	12.29	12.23
2028	42.59	87.37	38.87	82.36	7.98	2.77	6.52	1.02	32.13	29.33	32.58	29.73	13.73	13.68	12.26	12.20
2029	42.49	87.15	38.77	82.16	7.96	2.77	6.50	1.02	32.05	29.26	32.50	29.65	13.69	13.64	12.23	12.17
2030	42.38	86.93	38.68	81.96	7.94	2.76	6.48	1.02	31.97	29.19	32.42	29.58	13.66	13.61	12.20	12.14

Table C.56. Commercial Lodging End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	12.83	27.27	11.40	24.81	11.59	3.09	10.64	1.47	12.48	12.10	12.73	12.31	3.20	3.21	2.91	2.91
2005	12.80	27.21	11.38	24.74	11.56	3.08	10.62	1.46	12.45	12.07	12.69	12.28	3.20	3.20	2.91	2.90
2006	12.77	27.14	11.35	24.68	11.53	3.07	10.59	1.46	12.42	12.04	12.66	12.25	3.19	3.19	2.90	2.89
2007	12.74	27.07	11.32	24.62	11.51	3.07	10.56	1.46	12.39	12.01	12.63	12.22	3.18	3.19	2.89	2.89
2008	12.71	27.00	11.29	24.56	11.48	3.06	10.54	1.45	12.36	11.98	12.60	12.19	3.17	3.18	2.89	2.88
2009	12.68	26.94	11.26	24.50	11.45	3.05	10.51	1.45	12.33	11.95	12.57	12.16	3.16	3.17	2.88	2.87
2010	12.64	26.87	11.24	24.44	11.42	3.04	10.49	1.45	12.30	11.92	12.54	12.13	3.16	3.16	2.87	2.86
2011	12.61	26.80	11.21	24.38	11.39	3.04	10.46	1.44	12.27	11.89	12.51	12.10	3.15	3.16	2.86	2.86
2012	12.58	26.74	11.18	24.32	11.36	3.03	10.43	1.44	12.24	11.86	12.48	12.07	3.14	3.15	2.86	2.85
2013	12.55	26.67	11.15	24.26	11.34	3.02	10.41	1.43	12.21	11.83	12.45	12.04	3.13	3.14	2.85	2.84
2014	12.52	26.61	11.12	24.20	11.31	3.01	10.38	1.43	12.18	11.80	12.41	12.01	3.12	3.13	2.84	2.84
2015	12.49	26.54	11.10	24.14	11.28	3.01	10.36	1.43	12.15	11.77	12.38	11.98	3.12	3.12	2.84	2.83
2016	12.46	26.48	11.07	24.08	11.25	3.00	10.33	1.42	12.12	11.74	12.35	11.95	3.11	3.12	2.83	2.82
2017	12.43	26.41	11.04	24.02	11.22	2.99	10.31	1.42	12.09	11.71	12.32	11.92	3.10	3.11	2.82	2.82
2018	12.40	26.34	11.02	23.96	11.20	2.98	10.28	1.42	12.06	11.69	12.29	11.89	3.09	3.10	2.82	2.81
2019	12.37	26.28	10.99	23.90	11.17	2.98	10.26	1.41	12.03	11.66	12.26	11.86	3.09	3.09	2.81	2.80
2020	12.34	26.21	10.96	23.84	11.14	2.97	10.23	1.41	12.00	11.63	12.23	11.83	3.08	3.09	2.80	2.79
2021	12.30	26.15	10.93	23.78	11.11	2.96	10.20	1.41	11.97	11.60	12.20	11.80	3.07	3.08	2.79	2.79
2022	12.27	26.08	10.91	23.72	11.09	2.95	10.18	1.40	11.94	11.57	12.17	11.77	3.06	3.07	2.79	2.78
2023	12.24	26.02	10.88	23.67	11.06	2.95	10.15	1.40	11.91	11.54	12.14	11.74	3.06	3.06	2.78	2.77
2024	12.21	25.96	10.85	23.61	11.03	2.94	10.13	1.40	11.88	11.51	12.11	11.71	3.05	3.06	2.77	2.77
2025	12.18	25.89	10.83	23.55	11.00	2.93	10.10	1.39	11.85	11.48	12.08	11.68	3.04	3.05	2.77	2.76
2026	12.15	25.83	10.80	23.49	10.98	2.92	10.08	1.39	11.82	11.46	12.05	11.66	3.03	3.04	2.76	2.75
2027	12.12	25.76	10.77	23.43	10.95	2.92	10.05	1.39	11.79	11.43	12.02	11.63	3.03	3.03	2.75	2.75
2028	12.09	25.70	10.75	23.38	10.92	2.91	10.03	1.38	11.76	11.40	11.99	11.60	3.02	3.03	2.75	2.74
2029	12.06	25.64	10.72	23.32	10.90	2.90	10.00	1.38	11.74	11.37	11.96	11.57	3.01	3.02	2.74	2.73
2030	12.03	25.57	10.69	23.26	10.87	2.90	9.98	1.38	11.71	11.34	11.93	11.54	3.00	3.01	2.73	2.73

Table C.57. Commercial Mercantile/Service End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	20.09	43.96	19.82	41.91	24.60	6.46	15.68	4.44	0.85	0.79	0.87	0.81	10.24	10.22	9.49	9.51
2005	20.04	43.85	19.77	41.81	24.54	6.44	15.65	4.43	0.85	0.79	0.87	0.81	10.21	10.20	9.46	9.48
2006	19.99	43.75	19.72	41.71	24.48	6.43	15.61	4.42	0.84	0.79	0.87	0.81	10.19	10.17	9.44	9.46
2007	19.94	43.64	19.67	41.60	24.42	6.41	15.57	4.41	0.84	0.79	0.87	0.81	10.16	10.14	9.41	9.44
2008	19.89	43.53	19.62	41.50	24.36	6.39	15.53	4.40	0.84	0.78	0.87	0.81	10.14	10.12	9.39	9.41
2009	19.84	43.42	19.58	41.40	24.30	6.38	15.49	4.39	0.84	0.78	0.86	0.80	10.11	10.09	9.37	9.39
2010	19.79	43.32	19.53	41.30	24.24	6.36	15.45	4.37	0.84	0.78	0.86	0.80	10.09	10.07	9.35	9.37
2011	19.74	43.21	19.48	41.19	24.18	6.35	15.42	4.36	0.83	0.78	0.86	0.80	10.06	10.04	9.32	9.34
2012	19.69	43.10	19.43	41.09	24.12	6.33	15.38	4.35	0.83	0.78	0.86	0.80	10.04	10.02	9.30	9.32
2013	19.64	43.00	19.38	40.99	24.06	6.32	15.34	4.34	0.83	0.78	0.86	0.80	10.01	10.00	9.28	9.30
2014	19.60	42.89	19.34	40.89	24.00	6.30	15.30	4.33	0.83	0.77	0.85	0.79	9.99	9.97	9.25	9.28
2015	19.55	42.78	19.29	40.79	23.94	6.28	15.26	4.32	0.83	0.77	0.85	0.79	9.96	9.95	9.23	9.25
2016	19.50	42.68	19.24	40.69	23.88	6.27	15.23	4.31	0.82	0.77	0.85	0.79	9.94	9.92	9.21	9.23
2017	19.45	42.57	19.19	40.59	23.82	6.25	15.19	4.30	0.82	0.77	0.85	0.79	9.91	9.90	9.18	9.21
2018	19.40	42.47	19.14	40.49	23.76	6.24	15.15	4.29	0.82	0.77	0.85	0.79	9.89	9.87	9.16	9.18
2019	19.36	42.36	19.10	40.39	23.70	6.22	15.11	4.28	0.82	0.76	0.84	0.78	9.86	9.85	9.14	9.16
2020	19.31	42.26	19.05	40.29	23.64	6.21	15.08	4.27	0.82	0.76	0.84	0.78	9.84	9.82	9.12	9.14
2021	19.26	42.15	19.00	40.19	23.59	6.19	15.04	4.26	0.81	0.76	0.84	0.78	9.82	9.80	9.09	9.12
2022	19.21	42.05	18.96	40.09	23.53	6.18	15.00	4.25	0.81	0.76	0.84	0.78	9.79	9.78	9.07	9.09
2023	19.16	41.94	18.91	39.99	23.47	6.16	14.96	4.24	0.81	0.76	0.83	0.78	9.77	9.75	9.05	9.07
2024	19.12	41.84	18.86	39.89	23.41	6.15	14.93	4.23	0.81	0.75	0.83	0.78	9.74	9.73	9.03	9.05
2025	19.07	41.74	18.82	39.79	23.35	6.13	14.89	4.22	0.81	0.75	0.83	0.77	9.72	9.70	9.00	9.03
2026	19.02	41.63	18.77	39.69	23.30	6.12	14.85	4.21	0.80	0.75	0.83	0.77	9.70	9.68	8.98	9.00
2027	18.98	41.53	18.72	39.59	23.24	6.10	14.82	4.19	0.80	0.75	0.83	0.77	9.67	9.65	8.96	8.98
2028	18.93	41.43	18.68	39.50	23.18	6.09	14.78	4.18	0.80	0.75	0.82	0.77	9.65	9.63	8.94	8.96
2029	18.88	41.33	18.63	39.40	23.12	6.07	14.74	4.17	0.80	0.75	0.82	0.77	9.62	9.61	8.92	8.94
2030	18.84	41.22	18.58	39.30	23.07	6.06	14.71	4.16	0.80	0.74	0.82	0.76	9.60	9.58	8.89	8.92

Table C.58. Commercial Office-Large End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	24.49	38.82	21.60	35.11	24.73	13.94	23.22	10.08	0.60	0.56	0.62	0.57	5.65	5.64	4.73	4.72
2005	24.43	38.73	21.55	35.02	24.67	13.90	23.16	10.05	0.60	0.56	0.62	0.57	5.63	5.63	4.72	4.71
2006	24.37	38.63	21.49	34.94	24.61	13.87	23.10	10.03	0.60	0.56	0.62	0.57	5.62	5.62	4.71	4.70
2007	24.31	38.54	21.44	34.85	24.55	13.83	23.05	10.00	0.60	0.56	0.61	0.57	5.60	5.60	4.70	4.69
2008	24.25	38.44	21.39	34.77	24.49	13.80	22.99	9.98	0.60	0.55	0.61	0.56	5.59	5.59	4.69	4.68
2009	24.19	38.35	21.33	34.68	24.42	13.77	22.93	9.95	0.60	0.55	0.61	0.56	5.58	5.57	4.68	4.67
2010	24.13	38.25	21.28	34.59	24.36	13.73	22.88	9.93	0.59	0.55	0.61	0.56	5.56	5.56	4.67	4.65
2011	24.07	38.16	21.23	34.51	24.30	13.70	22.82	9.90	0.59	0.55	0.61	0.56	5.55	5.55	4.65	4.64
2012	24.01	38.06	21.18	34.42	24.24	13.66	22.76	9.88	0.59	0.55	0.61	0.56	5.54	5.53	4.64	4.63
2013	23.95	37.97	21.12	34.34	24.18	13.63	22.71	9.85	0.59	0.55	0.60	0.56	5.52	5.52	4.63	4.62
2014	23.89	37.87	21.07	34.25	24.12	13.60	22.65	9.83	0.59	0.55	0.60	0.56	5.51	5.50	4.62	4.61
2015	23.84	37.78	21.02	34.17	24.06	13.56	22.60	9.80	0.59	0.54	0.60	0.55	5.49	5.49	4.61	4.60
2016	23.78	37.69	20.97	34.08	24.01	13.53	22.54	9.78	0.59	0.54	0.60	0.55	5.48	5.48	4.60	4.59
2017	23.72	37.59	20.91	34.00	23.95	13.50	22.48	9.76	0.58	0.54	0.60	0.55	5.47	5.46	4.58	4.57
2018	23.66	37.50	20.86	33.92	23.89	13.46	22.43	9.73	0.58	0.54	0.60	0.55	5.45	5.45	4.57	4.56
2019	23.60	37.41	20.81	33.83	23.83	13.43	22.37	9.71	0.58	0.54	0.60	0.55	5.44	5.44	4.56	4.55
2020	23.54	37.32	20.76	33.75	23.77	13.40	22.32	9.68	0.58	0.54	0.59	0.55	5.43	5.42	4.55	4.54
2021	23.48	37.22	20.71	33.66	23.71	13.36	22.26	9.66	0.58	0.54	0.59	0.55	5.41	5.41	4.54	4.53
2022	23.43	37.13	20.66	33.58	23.65	13.33	22.21	9.64	0.58	0.54	0.59	0.54	5.40	5.40	4.53	4.52
2023	23.37	37.04	20.61	33.50	23.59	13.30	22.15	9.61	0.58	0.53	0.59	0.54	5.39	5.38	4.52	4.51
2024	23.31	36.95	20.56	33.42	23.53	13.26	22.10	9.59	0.57	0.53	0.59	0.54	5.37	5.37	4.51	4.50
2025	23.25	36.86	20.50	33.33	23.48	13.23	22.04	9.56	0.57	0.53	0.59	0.54	5.36	5.36	4.50	4.49
2026	23.20	36.77	20.45	33.25	23.42	13.20	21.99	9.54	0.57	0.53	0.59	0.54	5.35	5.34	4.48	4.47
2027	23.14	36.68	20.40	33.17	23.36	13.17	21.93	9.52	0.57	0.53	0.58	0.54	5.33	5.33	4.47	4.46
2028	23.08	36.58	20.35	33.09	23.30	13.13	21.88	9.49	0.57	0.53	0.58	0.54	5.32	5.32	4.46	4.45
2029	23.02	36.49	20.30	33.00	23.25	13.10	21.83	9.47	0.57	0.53	0.58	0.54	5.31	5.30	4.45	4.44
2030	22.97	36.40	20.25	32.92	23.19	13.07	21.77	9.45	0.57	0.52	0.58	0.53	5.29	5.29	4.44	4.43

Table C.59. Commercial Office-Small End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	22.12	39.10	18.01	32.73	19.78	7.36	20.47	5.18	0.72	0.68	0.74	0.69	5.95	5.86	5.02	4.92
2005	22.07	39.00	17.97	32.64	19.73	7.34	20.42	5.17	0.72	0.68	0.73	0.69	5.93	5.85	5.00	4.91
2006	22.01	38.90	17.93	32.56	19.68	7.32	20.37	5.15	0.72	0.68	0.73	0.69	5.92	5.83	4.99	4.90
2007	21.96	38.81	17.88	32.48	19.64	7.30	20.32	5.14	0.72	0.68	0.73	0.69	5.90	5.82	4.98	4.89
2008	21.90	38.71	17.84	32.40	19.59	7.29	20.27	5.13	0.72	0.67	0.73	0.68	5.89	5.80	4.97	4.87
2009	21.85	38.61	17.79	32.32	19.54	7.27	20.22	5.12	0.72	0.67	0.73	0.68	5.87	5.79	4.96	4.86
2010	21.80	38.52	17.75	32.24	19.49	7.25	20.17	5.10	0.71	0.67	0.73	0.68	5.86	5.78	4.94	4.85
2011	21.74	38.42	17.70	32.16	19.44	7.23	20.12	5.09	0.71	0.67	0.72	0.68	5.84	5.76	4.93	4.84
2012	21.69	38.33	17.66	32.08	19.39	7.21	20.07	5.08	0.71	0.67	0.72	0.68	5.83	5.75	4.92	4.83
2013	21.63	38.23	17.62	32.00	19.35	7.20	20.02	5.07	0.71	0.67	0.72	0.68	5.82	5.73	4.91	4.81
2014	21.58	38.14	17.57	31.93	19.30	7.18	19.97	5.05	0.71	0.67	0.72	0.67	5.80	5.72	4.89	4.80
2015	21.53	38.05	17.53	31.85	19.25	7.16	19.92	5.04	0.71	0.66	0.72	0.67	5.79	5.70	4.88	4.79
2016	21.47	37.95	17.49	31.77	19.20	7.14	19.87	5.03	0.70	0.66	0.71	0.67	5.77	5.69	4.87	4.78
2017	21.42	37.86	17.44	31.69	19.16	7.13	19.82	5.02	0.70	0.66	0.71	0.67	5.76	5.68	4.86	4.77
2018	21.37	37.76	17.40	31.61	19.11	7.11	19.77	5.00	0.70	0.66	0.71	0.67	5.74	5.66	4.85	4.75
2019	21.32	37.67	17.36	31.53	19.06	7.09	19.72	4.99	0.70	0.66	0.71	0.67	5.73	5.65	4.83	4.74
2020	21.26	37.58	17.31	31.45	19.01	7.07	19.68	4.98	0.70	0.66	0.71	0.66	5.72	5.63	4.82	4.73
2021	21.21	37.48	17.27	31.38	18.97	7.05	19.63	4.97	0.69	0.65	0.71	0.66	5.70	5.62	4.81	4.72
2022	21.16	37.39	17.23	31.30	18.92	7.04	19.58	4.95	0.69	0.65	0.70	0.66	5.69	5.61	4.80	4.71
2023	21.11	37.30	17.19	31.22	18.87	7.02	19.53	4.94	0.69	0.65	0.70	0.66	5.67	5.59	4.79	4.70
2024	21.05	37.21	17.14	31.15	18.83	7.00	19.48	4.93	0.69	0.65	0.70	0.66	5.66	5.58	4.77	4.68
2025	21.00	37.12	17.10	31.07	18.78	6.99	19.43	4.92	0.69	0.65	0.70	0.66	5.65	5.57	4.76	4.67
2026	20.95	37.02	17.06	30.99	18.73	6.97	19.39	4.91	0.69	0.65	0.70	0.65	5.63	5.55	4.75	4.66
2027	20.90	36.93	17.02	30.91	18.69	6.95	19.34	4.89	0.68	0.64	0.70	0.65	5.62	5.54	4.74	4.65
2028	20.85	36.84	16.98	30.84	18.64	6.93	19.29	4.88	0.68	0.64	0.69	0.65	5.60	5.52	4.73	4.64
2029	20.79	36.75	16.93	30.76	18.59	6.92	19.24	4.87	0.68	0.64	0.69	0.65	5.59	5.51	4.72	4.63
2030	20.74	36.66	16.89	30.69	18.55	6.90	19.19	4.86	0.68	0.64	0.69	0.65	5.58	5.50	4.70	4.62

Table C.60. Commercial Other End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	5.55	19.03	5.97	17.20	29.84	7.97	17.24	3.94	0.34	0.33	0.35	0.34	4.52	4.51	4.35	4.38
2005	5.54	18.98	5.96	17.16	29.76	7.95	17.19	3.93	0.34	0.33	0.35	0.34	4.51	4.50	4.34	4.37
2006	5.53	18.93	5.94	17.12	29.69	7.93	17.15	3.92	0.34	0.33	0.35	0.34	4.49	4.49	4.33	4.36
2007	5.51	18.88	5.93	17.07	29.61	7.91	17.11	3.91	0.34	0.33	0.35	0.34	4.48	4.48	4.32	4.35
2008	5.50	18.84	5.91	17.03	29.54	7.89	17.07	3.90	0.34	0.32	0.35	0.34	4.47	4.47	4.31	4.34
2009	5.49	18.79	5.90	16.99	29.47	7.88	17.02	3.89	0.33	0.32	0.35	0.33	4.46	4.46	4.30	4.33
2010	5.47	18.74	5.88	16.95	29.40	7.86	16.98	3.88	0.33	0.32	0.35	0.33	4.45	4.45	4.29	4.32
2011	5.46	18.70	5.87	16.91	29.32	7.84	16.94	3.87	0.33	0.32	0.35	0.33	4.44	4.44	4.28	4.31
2012	5.45	18.65	5.85	16.86	29.25	7.82	16.90	3.86	0.33	0.32	0.35	0.33	4.43	4.43	4.27	4.30
2013	5.43	18.61	5.84	16.82	29.18	7.80	16.86	3.85	0.33	0.32	0.34	0.33	4.42	4.41	4.26	4.29
2014	5.42	18.56	5.82	16.78	29.11	7.78	16.82	3.84	0.33	0.32	0.34	0.33	4.41	4.40	4.25	4.28
2015	5.41	18.51	5.81	16.74	29.03	7.76	16.77	3.83	0.33	0.32	0.34	0.33	4.40	4.39	4.24	4.27
2016	5.39	18.47	5.80	16.70	28.96	7.74	16.73	3.82	0.33	0.32	0.34	0.33	4.38	4.38	4.23	4.26
2017	5.38	18.42	5.78	16.66	28.89	7.72	16.69	3.81	0.33	0.32	0.34	0.33	4.37	4.37	4.22	4.25
2018	5.37	18.38	5.77	16.62	28.82	7.70	16.65	3.80	0.33	0.32	0.34	0.33	4.36	4.36	4.20	4.24
2019	5.35	18.33	5.75	16.57	28.75	7.68	16.61	3.79	0.33	0.32	0.34	0.33	4.35	4.35	4.19	4.22
2020	5.34	18.29	5.74	16.53	28.68	7.66	16.57	3.78	0.33	0.32	0.34	0.33	4.34	4.34	4.18	4.21
2021	5.33	18.24	5.72	16.49	28.61	7.64	16.53	3.77	0.32	0.31	0.34	0.33	4.33	4.33	4.17	4.20
2022	5.31	18.20	5.71	16.45	28.54	7.63	16.49	3.76	0.32	0.31	0.34	0.32	4.32	4.32	4.16	4.19
2023	5.30	18.15	5.70	16.41	28.46	7.61	16.44	3.76	0.32	0.31	0.34	0.32	4.31	4.31	4.15	4.18
2024	5.29	18.11	5.68	16.37	28.39	7.59	16.40	3.75	0.32	0.31	0.34	0.32	4.30	4.30	4.14	4.17
2025	5.27	18.06	5.67	16.33	28.32	7.57	16.36	3.74	0.32	0.31	0.33	0.32	4.29	4.29	4.13	4.16
2026	5.26	18.02	5.65	16.29	28.25	7.55	16.32	3.73	0.32	0.31	0.33	0.32	4.28	4.28	4.12	4.15
2027	5.25	17.97	5.64	16.25	28.18	7.53	16.28	3.72	0.32	0.31	0.33	0.32	4.27	4.26	4.11	4.14
2028	5.23	17.93	5.63	16.21	28.11	7.51	16.24	3.71	0.32	0.31	0.33	0.32	4.26	4.25	4.10	4.13
2029	5.22	17.88	5.61	16.17	28.05	7.49	16.20	3.70	0.32	0.31	0.33	0.32	4.25	4.24	4.09	4.12
2030	5.21	17.84	5.60	16.13	27.98	7.48	16.16	3.69	0.32	0.31	0.33	0.32	4.24	4.23	4.08	4.11

Table C.61. Commercial Warehouse End-Use Loads

Year	Cool (kBtu/SF)				Heat (kBtu/SF)				Water Heat (kBtu/SF)				Light (kWh/SF)			
	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South	Exist North	Exist South	New North	New South
2004	0.18	6.88	0.14	3.60	24.55	6.56	12.21	1.63	0.23	0.24	0.25	0.25	2.50	2.50	2.44	2.44
2005	0.18	6.87	0.14	3.59	24.49	6.54	12.18	1.63	0.23	0.23	0.25	0.25	2.50	2.50	2.43	2.43
2006	0.18	6.85	0.14	3.58	24.43	6.52	12.15	1.63	0.23	0.23	0.25	0.25	2.49	2.49	2.43	2.43
2007	0.18	6.83	0.14	3.57	24.37	6.51	12.12	1.62	0.23	0.23	0.25	0.24	2.48	2.49	2.42	2.42
2008	0.18	6.82	0.14	3.56	24.31	6.49	12.09	1.62	0.23	0.23	0.24	0.24	2.48	2.48	2.41	2.42
2009	0.18	6.80	0.14	3.55	24.25	6.48	12.06	1.61	0.23	0.23	0.24	0.24	2.47	2.47	2.41	2.41
2010	0.18	6.78	0.14	3.54	24.19	6.46	12.03	1.61	0.23	0.23	0.24	0.24	2.47	2.47	2.40	2.40
2011	0.18	6.77	0.13	3.53	24.13	6.44	12.00	1.61	0.23	0.23	0.24	0.24	2.46	2.46	2.40	2.40
2012	0.18	6.75	0.13	3.52	24.07	6.43	11.97	1.60	0.23	0.23	0.24	0.24	2.45	2.45	2.39	2.39
2013	0.18	6.73	0.13	3.52	24.01	6.41	11.94	1.60	0.23	0.23	0.24	0.24	2.45	2.45	2.38	2.39
2014	0.18	6.72	0.13	3.51	23.95	6.40	11.91	1.59	0.23	0.23	0.24	0.24	2.44	2.44	2.38	2.38
2015	0.18	6.70	0.13	3.50	23.90	6.38	11.88	1.59	0.23	0.23	0.24	0.24	2.44	2.44	2.37	2.37
2016	0.18	6.68	0.13	3.49	23.84	6.37	11.85	1.59	0.23	0.23	0.24	0.24	2.43	2.43	2.37	2.37
2017	0.18	6.67	0.13	3.48	23.78	6.35	11.82	1.58	0.23	0.23	0.24	0.24	2.42	2.42	2.36	2.36
2018	0.18	6.65	0.13	3.47	23.72	6.33	11.79	1.58	0.23	0.23	0.24	0.24	2.42	2.42	2.35	2.36
2019	0.18	6.63	0.13	3.46	23.66	6.32	11.76	1.57	0.23	0.23	0.24	0.24	2.41	2.41	2.35	2.35
2020	0.18	6.62	0.13	3.46	23.60	6.30	11.73	1.57	0.22	0.23	0.24	0.24	2.41	2.41	2.34	2.34
2021	0.18	6.60	0.13	3.45	23.54	6.29	11.71	1.57	0.22	0.23	0.24	0.24	2.40	2.40	2.34	2.34
2022	0.18	6.58	0.13	3.44	23.48	6.27	11.68	1.56	0.22	0.23	0.24	0.24	2.39	2.39	2.33	2.33
2023	0.18	6.57	0.13	3.43	23.43	6.26	11.65	1.56	0.22	0.22	0.24	0.23	2.39	2.39	2.33	2.33
2024	0.17	6.55	0.13	3.42	23.37	6.24	11.62	1.56	0.22	0.22	0.24	0.23	2.38	2.38	2.32	2.32
2025	0.17	6.54	0.13	3.41	23.31	6.22	11.59	1.55	0.22	0.22	0.23	0.23	2.38	2.38	2.31	2.32
2026	0.17	6.52	0.13	3.40	23.25	6.21	11.56	1.55	0.22	0.22	0.23	0.23	2.37	2.37	2.31	2.31
2027	0.17	6.50	0.13	3.40	23.20	6.19	11.53	1.54	0.22	0.22	0.23	0.23	2.36	2.37	2.30	2.30
2028	0.17	6.49	0.13	3.39	23.14	6.18	11.50	1.54	0.22	0.22	0.23	0.23	2.36	2.36	2.30	2.30
2029	0.17	6.47	0.13	3.38	23.08	6.16	11.48	1.54	0.22	0.22	0.23	0.23	2.35	2.35	2.29	2.29
2030	0.17	6.46	0.13	3.37	23.02	6.15	11.45	1.53	0.22	0.22	0.23	0.23	2.35	2.35	2.29	2.29

C.6 Lighting Interactions Factors

Changes in lighting impact the heating and cooling loads of a building because lights also produce heat. These interactions are accounted for through the development and use of lighting interaction factors.

C.6.1 Case Definition—Baseline

Baseline consumption in all buildings is the same as the baseline load data presented in Tables C.48 through C.61. Baseline loads were determined using NEMSFEDS, an iteration tool based on FEDS that allows a single case to be modified and run (loads only) by altering inputs to a [casename].ini file. In this manner a single case can be used to run a multi-dimensional matrix of all combinations of building type, size, vintage, location, occupancy, and lighting configurations. Statistical data of actual building size and vintage information were then used to combine the NEMSFEDS results into a location by building type results matrix where each building type is of the weighted average size and weighted average vintage (for existing) or 2000 vintage for new buildings.

Values were determined for all combinations of the following:

- Commercial, residential, and industrial building types
- New and existing buildings
- Nine census regions (and north and south for BESET).

C.6.2 Case Definition—Variation from Baseline

Lighting loads were decreased from 100% to 0% with 10% steps. As a result of the decrease in lighting loads, the heating load increased and the cooling load decreased. The percentage increases in the heating load and percentage decreases in the cooling load were then determined at each of the steps. Lastly, the results were converted via regression to equations (one for heat and one for cooling for each combination of building type, new/existing, and location) where the only input is the percentage reduction in the lighting load. The regression equations are of the form:

Heat $\Delta heat = a * \Delta L^{b}$

Cool $\Delta cool = c * \Delta L^{2} + d * \Delta L$

Where:

a, b, c, & *d* are coefficients (presented in Tables C.62 through C.65)
Δheat = the fractional change in heating load
Δcool = the fractional change in cooling load
ΔL = the percentage reduction in lighting load

C.6.3 Specification

Because of the way this was modeled the implicit assumption is that a 20% penetration rate means that 20% of the lighting within all buildings of a certain type, vintage, and region get the BT/WIP technology. Hence the 20% value can be used directly. The alternative, which could also be easily modeled using the data generated in this activity, is that 20% of the buildings within a certain type, vintage, and region have 100% of the BT/WIP technology. This would require that a weighted average be developed (20% with 100% penetration and 80% with 0% penetration). For the time being we will ignore the later approach and focus on the former.

C.6.4 Caveats/Constraints

Application of the lighting interaction factors need to have an absolute limit on the heating and cooling load impacts. For example, an XX% increase in heating load (based on the equations) translates to YY MMBtu/yr; however, we know that the change in the heating load cannot exceed the lighting load change. Hence, the actual load impacts (heating and cooling) are programmed as the minimum of 1) the change in the lighting load and 2) the change in the heating load as determined by the product of the percentage reduction (from the regression equation) and the unadjusted heating. This same constraint must be applied to the cooling as well.

Tables C.62 through C.65 present the lighting interaction factors. Note that the coefficients contained in the tables reference the equations presented above.

Table C.62. Residential Heat Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient a	Coefficient b
Mobile Home	Existing	North	0.0004270	1.0037380
Mobile Home	Existing	South	0.0008340	1.0096560
Mobile Home	New	North	0.0005060	1.0044900
Mobile Home	New	South	0.0010170	1.0109510
Multi Family	Existing	North	0.0021250	1.0226010
Multi Family	Existing	South	0.0046220	1.1273510
Multi Family	New	North	0.0024560	1.0280980
Multi Family	New	South	0.0044600	1.2090270
Single Family	Existing	North	0.0009330	1.0110920
Single Family	Existing	South	0.0023330	1.0375540
Single Family	New	North	0.0011870	1.0139700
Single Family	New	South	0.0032970	1.0707780

Table C.63. Residential Cool Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient c	Coefficient d
Mobile Home	Existing	North	0.0000002	-0.0006579
Mobile Home	Existing	South	0.0000002	-0.0005977
Mobile Home	New	North	0.0000002	-0.0007648
Mobile Home	New	South	0.0000002	-0.0006953
Multi Family	Existing	North	0.0000016	-0.0021230
Multi Family	Existing	South	0.0000011	-0.0018487
Multi Family	New	North	0.0000014	-0.0022249
Multi Family	New	South	0.0000013	-0.0019758
Single Family	Existing	North	0.0000008	-0.0016490
Single Family	Existing	South	0.0000005	-0.0013311
Single Family	New	North	0.0000012	-0.0019544
Single Family	New	South	0.0000007	-0.0015623

Table C.64. Commercial Heat Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient a	Coefficient b
Assembly	Existing	North	0.0021350	1.0425220
Assembly	Existing	South	0.0027620	1.0671970
Assembly	New	North	0.0023980	1.0471820
Assembly	New	South	0.0033980	1.0884520
Education	Existing	North	0.0025850	1.0533410
Education	Existing	South	0.0036940	1.1028510
Education	New	North	0.0030640	1.0560240
Education	New	South	0.0037390	1.1107990
Food Sales	Existing	North	0.0080300	1.1614610
Food Sales	Existing	South	0.0048320	1.5397610
Food Sales	New	North	0.0136250	1.1885550
Food Sales	New	South	0.0107590	1.4628680
Food Service	Existing	North	0.0045980	1.1173690
Food Service	Existing	South	0.0055760	1.2109920
Food Service	New	North	0.0066790	1.1608490
Food Service	New	South	0.0048350	1.6300790
Health Care	Existing	North	0.0099260	1.1141170
Health Care	Existing	South	0.0104810	1.2452230
Health Care	New	North	0.0099180	1.1152260
Health Care	New	South	0.0051680	1.9017270
Lodging	Existing	North	0.0051560	1.0452890
Lodging	Existing	South	0.0062920	1.2579540
Lodging	New	North	0.0048340	1.0343510
Lodging	New	South	0.0043410	1.5146920

Building Type	Vintage	Region	Coefficient a	Coefficient b
Merc/Service	Existing	North	0.0076920	1.1300060
Merc/Service	Existing	South	0.0039690	1.5529340
Merc/Service	New	North	0.0106140	1.1696480
Merc/Service	New	South	0.0041970	1.5951010
Office-Large	Existing	North	0.0017950	1.0256950
Office-Large	Existing	South	0.0020350	1.0394010
Office-Large	New	North	0.0015750	1.0226400
Office-Large	New	South	0.0022050	1.0464980
Office-Small	Existing	North	0.0025640	1.0360660
Office-Small	Existing	South	0.0034230	1.0698730
Office-Small	New	North	0.0020530	1.0284990
Office-Small	New	South	0.0039030	1.0860080
Other	Existing	North	0.0031740	1.0475370
Other	Existing	South	0.0029860	1.3700020
Other	New	North	0.0049840	1.0779460
Other	New	South	0.0046370	1.4307770
Warehouse	Existing	North	0.0024270	1.0346750
Warehouse	Existing	South	0.0030460	1.0856270
Warehouse	New	North	0.0047010	1.0770960
Warehouse	New	South	0.0070410	1.2944710

Table C.65. Commercial Cool Lighting Interaction Factors

Building Type	Vintage	Region	Coefficient c	Coefficient d
Assembly	Existing	North	0.0000112	-0.0067194
Assembly	Existing	South	0.0000033	-0.0047299
Assembly	New	North	0.0000123	-0.0071985
Assembly	New	South	0.0000040	-0.0051491
Education	Existing	North	0.0000067	-0.0050878
Education	Existing	South	0.0000026	-0.0037712
Education	New	North	0.0000068	-0.0054184
Education	New	South	0.0000032	-0.0039730
Food Sales	Existing	North	0.0000130	-0.0072780
Food Sales	Existing	South	0.0000057	-0.0055939
Food Sales	New	North	0.0000133	-0.0072755
Food Sales	New	South	0.0000064	-0.0057319
Food Service	Existing	North	0.0000050	-0.0046340
Food Service	Existing	South	0.0000015	-0.0034510
Food Service	New	North	0.0000052	-0.0048961
Food Service	New	South	0.0000013	-0.0036404
Health Care	Existing	North	0.0000101	-0.0062786
Health Care	Existing	South	0.0000008	-0.0046037
Health Care	New	North	0.0000070	-0.0055847
Health Care	New	South	-0.0000012	-0.0041603
Lodging	Existing	North	0.0000047	-0.0045271
Lodging	Existing	South	0.0000034	-0.0036586
Lodging	New	North	0.0000056	-0.0047403
Lodging	New	South	0.0000020	-0.0037478
Merc/Service	Existing	North	0.0000247	-0.0102030
Merc/Service	Existing	South	0.0000136	-0.0080290
Merc/Service	New	North	0.0000266	-0.0106650
Merc/Service	New	South	0.0000150	-0.0083544
Office-Large	Existing	North	0.0000014	-0.0049673
Office-Large	Existing	South	0.0000008	-0.0036900
Office-Large	New	North	0.0000011	-0.0044716
Office-Large	New	South	0.0000006	-0.0033358
Office-Small	Existing	North	0.0000042	-0.0052292
Office-Small	Existing	South	0.0000016	-0.0038771
Office-Small	New	North	0.0000043	-0.0051372
Office-Small	New	South	0.0000014	-0.0037777
Other	Existing	North	0.0000183	-0.0093593
Other	Existing	South	0.0000136	-0.0066405
Other	New	North	0.0000230	-0.0105200
Other	New	South	0.0000162	-0.0077043

Building Type	Vintage	Region	Coefficient c	Coefficient d
Warehouse	Existing	North	0.0000748	-0.0155040
Warehouse	Existing	South	0.0000450	-0.0105220
Warehouse	New	North	0.0001406	-0.0235170
Warehouse	New	South	0.0001005	-0.0180370

C.7 Emissions Coefficients

Tables C.66 through C.68 present the emissions coefficients used in the FY04 GPRA analysis to compute the emissions reductions. Emissions coefficients were provided by PBFA (EERE 2002, Appendix B).

Table C.66. Electricity Emissions Coefficients
(MMton/TBtu delivered)

Year	Carbon	SO2	Nox	VOCs	PM	CO
2004	0.056751	0.000643	0.000471	0.000009	0.000013	0.000072
2005	0.058195	0.000723	0.000500	0.000006	0.000016	0.000068
2006	0.057528	0.000789	0.000504	0.000006	0.000015	0.000062
2007	0.059937	0.000912	0.000539	0.000006	0.000018	0.000056
2008	0.058014	0.000885	0.000524	0.000006	0.000018	0.000054
2009	0.056075	0.000857	0.000509	0.000005	0.000018	0.000052
2010	0.054119	0.000830	0.000494	0.000005	0.000018	0.000050
2011	0.052904	0.000800	0.000481	0.000005	0.000018	0.000050
2012	0.051699	0.000770	0.000468	0.000005	0.000017	0.000050
2013	0.050505	0.000742	0.000456	0.000005	0.000016	0.000049
2014	0.049321	0.000713	0.000443	0.000005	0.000015	0.000049
2015	0.048148	0.000685	0.000431	0.000005	0.000015	0.000048
2016	0.047500	0.000669	0.000424	0.000005	0.000014	0.000048
2017	0.046855	0.000653	0.000418	0.000005	0.000014	0.000049
2018	0.046215	0.000637	0.000411	0.000005	0.000014	0.000049
2019	0.045579	0.000621	0.000404	0.000005	0.000014	0.000049
2020	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2021	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2022	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2023	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2024	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2025	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2026	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2027	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2028	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2029	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049
2030	0.044946	0.000606	0.000398	0.000005	0.000014	0.000049

Table C.67. Natural Gas Emissions Coefficients
(MMton/TBtu delivered)

Emission	Coefficient
Carbon	0.014400
SO2	0.000000
Nox	0.000106
VOCs	0.000003
PM	0.000000
CO	0.000029

Table C.68. Fuel Oil Emissions Coefficients
(MMton/TBtu delivered)

Emission	Coefficient
Carbon	0.019750
SO2	0.000527
Nox	0.000140
VOCs	0.000004
PM	0.000007
CO	0.000013

C.8 Fuel Prices

Tables C.69 through C.70 present the fuel prices used in the FY04 GPRA analysis to calculate the consumer cost (energy cost) savings. Fuel prices were provided by PBFA (EERE 2002, Appendix B).

Table C.69. Residential Fuel Prices (1999 $/MMBtu)

Year	Electricity	Natural Gas	Fuel Oil
2004	22.33	6.65	7.33
2005	21.90	6.63	7.33
2006	22.07	6.61	7.26
2007	21.90	6.60	7.36
2008	21.89	6.58	7.41
2009	21.89	6.55	7.46
2010	21.88	6.53	7.51
2011	21.91	6.51	7.57
2012	21.93	6.49	7.63
2013	21.96	6.48	7.68
2014	21.98	6.46	7.74
2015	22.01	6.44	7.80
2016	22.04	6.46	7.84
2017	22.07	6.48	7.87
2018	22.11	6.51	7.91
2019	22.14	6.53	7.94
2020	22.17	6.55	7.98
2021	22.20	6.55	8.03
2022	22.23	6.55	8.08
2023	22.26	6.56	8.13
2024	22.29	6.56	8.18
2025	22.32	6.56	8.23
2026	22.35	6.56	8.28
2027	22.38	6.56	8.33
2028	22.41	6.57	8.39
2029	22.44	6.57	8.44
2030	22.47	6.57	8.49

Table C.70. Commercial Fuel Prices (1999 $/MMBtu)

Year	Electricity	Natural Gas	Fuel Oil
2004	20.38	5.27	5.12
2005	19.58	5.31	5.12
2006	19.07	5.35	5.05
2007	18.40	5.40	5.14
2008	18.14	5.43	5.19
2009	17.89	5.47	5.23
2010	17.63	5.50	5.28
2011	17.65	5.50	5.33
2012	17.67	5.50	5.39
2013	17.68	5.50	5.44
2014	17.70	5.50	5.50
2015	17.72	5.50	5.55
2016	17.80	5.54	5.59
2017	17.88	5.58	5.63
2018	17.96	5.63	5.67
2019	18.04	5.67	5.71
2020	18.12	5.71	5.75
2021	18.17	5.73	5.80
2022	18.22	5.75	5.85
2023	18.26	5.77	5.90
2024	18.31	5.79	5.95
2025	18.36	5.81	6.00
2026	18.41	5.83	6.05
2027	18.46	5.85	6.11
2028	18.52	5.88	6.16
2029	18.57	5.90	6.22
2030	18.62	5.92	6.27

C.9 Electricity Conversion Factors

Table C.71 presents the marginal heat rates for primary and delivered electricity, and the resulting electricity conversion factors which were used in the FY 2004 GPRA analysis to convert delivered (site) electricity to primary electricity. Heat rates were provided by PBFA (EERE 2002, Appendix B).

Table C.71. Heat Rates and Resulting Electricity Conversion Factors(1)

Year	Heat Rate	Delivered Electric Heat Rate	Electricity Conversion Factor
2004	10713	3413	3.14
2005	10593	3413	3.10
2006	10126	3413	2.97
2007	10102	3413	2.96
2008	9741	3413	2.85
2009	9380	3413	2.75
2010	9019	3413	2.64
2011	8868	3413	2.60
2012	8718	3413	2.55
2013	8567	3413	2.51
2014	8417	3413	2.47
2015	8266	3413	2.42
2016	8191	3413	2.40
2017	8116	3413	2.38
2018	8041	3413	2.36
2019	7966	3413	2.33
2020	7891	3413	2.31
2021	7891	3413	2.31
2022	7891	3413	2.31
2023	7891	3413	2.31
2024	7891	3413	2.31
2025	7891	3413	2.31
2026	7891	3413	2.31
2027	7891	3413	2.31
2028	7891	3413	2.31
2029	7891	3413	2.31
2030	7891	3413	2.31
(1) Heat rates for 2008-2009, 2011-2014, 2016-2019, 2021-2024, and 2026-2029 extrapolated linearly.			