Appendix K – GPRA05 Weatherization and Intergovernmental Program Documentation

Introduction

Table 1 outlines the activities characterized for the GPRA 05 Weatherization and Intergovernmental Program. Characterizations and inputs for these activities were provided to EERE as inputs to EERE's integrated modeling effort.

Often such analysis requires the development and use of enabling or simplifying assumptions. In many cases, no citable sources exist for substantiating assumptions. Therefore, assumptions are developed through an iterative process with project managers, project contractors, and GPRA analysts. Often, we base these assumptions on project knowledge and experience, as there are varying degrees of corroborative studies available on which project information can be substantiated, depending on the maturity of the project.

Table 1. Building Technologies Subprograms, Projects, and Activities

<table>
<tr><th>Subprogram</th><th>Project</th><th>Activity</th></tr>
<tr><td>State Energy Program</td><td>State Energy Grants</td><td>Codes and Standards
Energy Audits
Rating and Labeling
Workshops/Training
Incentives
Retrofits
Loans and Grants
Technical Assistance</td></tr>
<tr><td>Weatherization Assistance</td><td>Weatherization Assistance</td><td>Weatherization Assistance</td></tr>
<tr><td rowspan="6">Gateway Deployment</td><td>Rebuild America</td><td>Rebuild America Deployment</td></tr>
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Dishwashers
Windows</td></tr>
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</table>

1.0 State Energy Program

1.1 State Energy Program

1.1.1 Target Market

Project Description. The State Energy Program provides financial assistance to States, enabling State governments to target their own high priority energy needs and expand clean energy choices for their residents and businesses. With these funds and the resources leveraged by them, the State and Territory Energy Offices develop and manage a variety of programs geared to increase energy efficiency, reduce energy use and costs, develop alternative energy and renewable energy sources, promote environmentally conscious economic development, and reduce reliance on oil produced outside of the United States.

Market Description. The market includes all markets (including buildings, transportation, industry, and power technologies), except new construction and all categories of energy end use.

Baseline technology improvements. For this analysis, the Pacific Northwest National Laboratory (PNNL) did not suggest any changes in technology improvements apart from the Energy Information Administration (EIA) baseline.

1.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered.

- Cleaner air and water
- Increased jobs
- Enhanced national security
- Increased economic competitiveness in world markets
- Mitigation of global warming.[1]

1.1.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[4].

Technical Characteristics. For the FY05 GPRA metrics, the State Energy Program (SEP) is characterized, based on the budget request and leveraged funds. Based on the report, *Estimating Energy and Cost Savings and Emissions Reductions for the State Energy Program Based on*

Enumeration Indicators Data (Schweitzer, et al. 2003)[(2)], eight activities (referred to in the report as program areas) supported by SEP were selected to represent the project. These activities—Codes and Standards, Energy Audits, Rating and Labeling, Workshops/Training, Incentives, Retrofits, Loans and Grants, and Technical Assistance—comprised approximately 98% of the total estimated savings reported. Because the Schweitzer et al study only received responses from 20 states (representing about half of the SEP funding), PNNL assumed that the responses were representative of the whole program, so all indicators produced were multiplied by two to approximate a national total.

Because Schweitzer et al. did not differentiate between funds provided directly by SEP as part of the Formula Grants project and those that SEP administers on behalf of other EERE projects (e.g., Rebuild America, Training and Assistance for Codes) through the Special Projects grants, the methodology was modified in some cases to reduce the likelihood of double-counting the savings estimates. Therefore, outputs resulting from Special Project funding should be allocated to the originating project for purposes of this effort. As an example, outputs resulting from funding that originates in the Training and Assistance for Codes project, but is administered by SEP through Special Projects, should be allocated to Training and Assistance for Codes.

<u>Codes and Standards.</u> Based on the estimated savings contained in Schweitzer et al, PNNL determined that the greatest area of potential overlap between Formula Grants and Special Projects would come about through the Codes and Standards activities. The Schweitzer report provided funding data for each of the activities, with total SEP (Formula Grant and Special Project) funding of about $4 million allocated by the responding states to Codes and Standards activities. Based on information provided by the Building Energy Codes Project on Special Project funding, approximately $1.6 million of that amount would have originated within Training and Assistance for Codes. PNNL determined that codes activities are therefore also being funded out of the SEP Formula Grants, and that some level of savings should be allocated to SEP for codes activities.

For consistency, the estimated savings due to the Codes and Standards activities funded by the SEP were based on the savings estimates produced for the Training and Assistance for Codes project. The Schweitzer et al section on Rating and Labeling cited a study (Feldman and Tannenbaum 2000) indicating that approximately 10% of Energy Star purchases are made as a result of state encouragement. PNNL applied this attribution percentage to the estimate developed for Training and Assistance for Codes, so that the original estimate has been allocated 10% to SEP and 90% to Training and Assistance for Codes.

<u>Energy Audits.</u> In Schweitzer et al, energy-audit calculations were based on three indicators: number of audits, square feet retrofit, and reported savings. For this effort, PNNL converted these three indicators to number of households and square footage of commercial floor space impacted.

Schweitzer et al provided a savings per audit of 6.8 MMBtu per household and 0.0167 MMBtu per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook*, approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 8% for residential space heating and cooling. Based on Tables 1.3.3 and 1.3.4 of the *Buildings Energy Databook*, approximately 126 kBtu/SF/yr are used by commercial space heating, space cooling, and lighting, yielding a load reduction of 13% for commercial space heating, space cooling, and lighting.

To convert the indicators into an estimated number of households, PNNL assumed that each residential audit represented one household, divided the total residential square feet retrofit by the report's assumed average square feet per household (1,600), and divided the estimated reported annual savings by the 6.8 MMBtu/HH figure. This yielded an estimate of approximately 5,500 households impacted by energy audits in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was multiplied by two to approximate a national total. This yielded a total annual estimate of 11,000 households impacted, or 0.014% of existing residential single-family buildings, in each year.

To convert the indicators into an estimated commercial square footage, PNNL assumed that each commercial audit represented one building multiplied by the average building size assumed in the report (14,500 square feet), used the square footage reported, and divided the estimated reported annual savings by the 0.0167 MMBtu/SF figure. This yielded an estimate of approximately 0.197 billion square feet impacted by energy audits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a national total, yielding a total annual estimate of 0.396 billion square feet impacted, or 1.576% of existing commercial office, education, and health-care floor space, in each year.

<u>Rating and Labeling.</u> Schweitzer et al provided a national per-device estimate for rating and labeling of approximately 895,400 MMBtu per year. While the report allocated these savings to states (based on population) to determine an estimate of savings for states reporting estimates, the device savings were allocated equally across all states, because no forecast is available for determining which states would fund rating and labeling projects in the future. The equivalent savings per state is about 17,900 MMBtu per device (the national estimate divided by 50).

Of the responding states, two states reported that they funded rating and labeling activities for a total of 82 devices. To convert to a national representation, PNNL assumed that four states would fund rating and labeling activities in any given year, and that each state would cover approximately 40 devices, yielding a total of 160 devices saving energy. PNNL assumed that the savings would be effective for 15 years, and that they were attributable to electricity.

<u>Workshops/Training.</u> An estimate of 13.1% HVAC and 8% lighting savings attributable to workshops and training was provided by Schweitzer et al. PNNL translated these inputs to a 13% load reduction for space heating and space cooling, and an 8% load reduction in lighting within commercial buildings. According to the report, 19 of 20 states funded workshop and training activities, with a total of 5,600 trainees attending and a weighted average of four buildings influenced per trainee. To convert this to a national representation, PNNL assumed that 40 states would fund workshop/training activities in any given year, yielding approximately 11,800 trainees impacting a total of 47,000 buildings. There are currently about 4.7 million existing commercial buildings in the United States.[(3)] PNNL assumed that the relationship between the number of buildings influenced as a percentage of the total stock would be equivalent to the square footage influenced as a percentage of the total commercial square footage; therefore,

workshops and training were assumed to impact approximately 1% of the commercial building stock per year.

Incentives. According to Schweitzer et al, approximately 0.145 MMBtu are saved per rebate dollar. During FY 2000, the ratio of incentive funding to rebate value was approximately 1:39, the percentage of SEP funds spent on incentives within the responding states was 0.31%, and the amount of leveraged funds received for incentives was $1.78 per dollar of funding. Based on the FY 2005 request, PNNL assumed that approximately $355,000 dollars would be spent on incentive activities, equating to about $13.7 million in rebates for an annual savings of almost 2.0 TBtu. PNNL assumed that the savings would be in effect for 15 years.

Retrofits. Within Schweitzer et al, retrofit calculations were based on two indicators: number of retrofits and square feet retrofit. For this effort, PNNL converted these two indicators to number of households and square feet of commercial floor space impacted.

Schweitzer et al provided a savings per audit of 14.51 MMBtu per household and 18.8% per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook,* approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 17% for residential space heating and cooling. PNNL applied the 18.8% savings to commercial space heating, space cooling, and lighting.

To convert the indicators into an estimated number of households, PNNL assumed that each residential retrofit represented one household and divided the total residential square feet retrofit by the report's assumed average square feet per household (1,600). This yielded an estimate of approximately 20,600 households impacted by retrofits in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was multiplied by two to approximate a national total. This yielded a total annual estimate of 41,000 households impacted, or 0.051% of existing residential single-family buildings, in each year.

To convert the indicators into an estimated commercial square footage, PNNL assumed that each commercial retrofit represented one building multiplied by the average building size assumed in the report (14,500 square feet) and used the square footage reported. This yielded an estimate of approximately 0.028 billion square feet impacted by retrofits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a national total, yielding a total annual estimate of 0.056 billion square feet impacted, or 0.222% of existing commercial office, education, and health-care floor space, in each year.

Loans and Grants. According to Schweitzer et al, loans average 0.0164 million source Btu per dollar, and grants average 0.0178 million source Btu per dollar. For the GPRA effort, the lower, more conservative value was used for this analysis. During FY 2000, the percentage of SEP funds spent on incentives within the responding states was 21.7%; and the amount of leveraged funds received for incentives was $3.77 per dollar of funding. Based on the FY 2005 request, PNNL assumed that approximately $42.7 million dollars would be spent on loans and grants activities for an annual savings of about 0.001 TBtu. PNNL assumed that the savings would be in effect for 15 years.

Technical Assistance. Within Schweitzer et al, technical assistance calculations were based on the number of recommendations. For this effort, PNNL converted these two indicators to number of households and square feet of commercial floor space impacted.

The report provided a savings per recommendation of 9.0 MMBtu per household and 9.4% per square foot of commercial floor space. Based on Tables 1.2.3 and 1.2.4 of the *Buildings Energy Databook*, approximately 83 MMBtu/HH/yr are used by residential space heating and space cooling, yielding a load reduction of 11% for residential space heating and cooling. PNNL applied the 9.4% savings to commercial space heating, space cooling, and lighting.

To convert the recommendation indicator into an estimated number of households, PNNL assumed that each residential recommendation represented one household. This yielded an estimate of approximately 18,000 households impacted by technical assistance in any given year. Because the study only received responses from 20 states (representing about half of the SEP funding), that number was multiplied by two to approximate a national total. This yielded a total annual estimate of 36,000 households impacted, or 0.045% of existing residential single-family buildings, in each year.

To convert the recommendation indicator into an estimated commercial square footage, PNNL assumed that each commercial recommendation represented one building, and multiplied by the average building size assumed in the report (14,500 square feet). This yielded an estimate of approximately 0.009 billion square feet impacted by retrofits in any given year. As with the residential estimate, the commercial figure was also multiplied by two to approximate a national total, yielding a total annual estimate of 0.017 billion square feet impacted, or 0.069% of existing commercial office, education, and health-care floor space, in each year.

1.1.4 Sources

(1) *FY 2002 Budget Request – Data Bucket Report for State Formula Grants Program*.

(2) Schweitzer, M., D.W. Jones, L.G. Berry, and B.E. Tonn. 2003. *Estimating Energy and Cost Savings and Emissions Reductions for the State Energy Program Based on Enumeration Indicators Data*. ORNL/CON-487, Oak Ridge National Laboratory, Oak Ridge, TN

(3) *2003 Buildings Energy Databook* (internal DOE document). www.buildingsdatabook.eren.doe.gov.

(4) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

2.0 Weatherization Assistance

2.1 Weatherization Assistance

2.1.1 Target Market

Project Description. 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.

Weatherization Assistance provides technical assistance and formula grants to State and local weatherization agencies throughout the United States. A network of approximately 970 local agencies provide trained crews to perform weatherization services for eligible low-income households in single-family homes, multifamily dwellings, and mobile homes. Of the homes weatherized annually, 49% are occupied by an elderly person with special needs or a person with disabilities. All homes receive a comprehensive energy audit, which is a computerized assessment of a home's energy use and an analysis of which energy conservation measures are best for the home and a combination of those energy-saving measures are installed.

Market Description. The market includes households that are eligible for Federal assistance. Households are categorized as eligible for Federal assistance if the household income is below the Federal maximum standard of 150% of the poverty line or 60% of statewide median income, whichever is higher. Individual States can also set the standard at a lower level than the Federal maximum.[a] Target measures include air sealing; caulking and weather stripping; furnace and boiler tune-up, repair, and replacement; cooling system tune-up 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. About 34 million eligible low-income homes are included in the market.

Baseline technology improvements. For this analysis, PNNL did not suggest any changes in technology improvements apart from the EIA baseline.

2.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL employed the average household weatherization cost of $1,800(6); this estimate does not include training, technical assistance, and administrative costs. Incremental investment beyond this amount for Weatherization *Plus* homes, estimated at an average of $1,400 by the Weatherization project(6), was assumed to be provided by other organizations, that is by leveraged funds. **Table 2** shows the estimated total costs by region for *Plus* homes.

Table 2. Estimated Regional Costs for Weatherization *Plus* Homes

Region	Cost per *Plus* Household
South	$2861
Northeast	$3674
West	$1814
Midwest	$3429

[a] Eligibility requirements for Weatherization Assistance can be found at http://www.eere.energy.gov/weatherization/apply.html

2.1.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[7].

Technical Characteristics. 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[6]. **Table 3** shows the savings per household used for each region for the FY 2005 metrics.

Table 3. 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]

Of the units weatherized in FY 2005, nearly 50% 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 4**).

Table 4. 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 used 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 5** shows the allocation approaches used.

Table 5. Percent of Weatherized Households by Fuel Type

Primary Heating Fuel	% of Weatherized Households	Categorized As
Natural Gas Liquid Propane Gas	50.6 13.2	Natural Gas
Fuel Oil Kerosene Other (includes wood and coal)	16.0 3.2 7.5	Fuel Oil
Electricity	9.5	Electricity

The Department of Energy (DOE) budget and leveraged funding forecasts 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 6** shows the projection for regular and *Plus* households to be weatherized. PNNL assumed that the number of households weatherized for each category would be constant from 2011 through 2030.

Table 6. Projected Regular and *Plus* Households to be Weatherized

	2005	2006	2007	2008	2009	2010	2011
Total Households	222,395	224,096	225,830	227,599	229,403	231,243	233,119
Regular South	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Regular Northeast	26,778	27,006	27,239	27,476	27,717	27,963	28,213
Regular West	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Regular Midwest	34,538	34,833	35,134	35,441	35,755	36,076	36,403
Plus South	22,703	22,888	23,076	23,267	23,463	23,663	23,867
Plus Northeast	26,778	27.006	27,239	27,476	27,717	27,963	28,213
Plus West	27,177	27,321	27,466	27,615	27,766	27,920	28,077
Plus Midwest	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. The estimated savings level for each household category was further divided by household type and then by fuel type. Savings from each household weatherized were assumed to be in effect for 15 years; i.e., savings from households weatherized in 2005 were included in the annual total savings estimates for the years 2005 through 2019.

2.1.4 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.
(6) Eisenberg, J.F., Oak Ridge National Laboratory. 2001. Projections for the Weatherization Assistance Program, provided to PNNL in file "Projections02d230.xls."
(7) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

3.0 Gateway Deployment

This effort seeks to accomplish effective delivery of the full menu of efficiency and renewable resources aligned with clear community and customer focus. The activities focus on the end-user needs, rather than individual EERE programs. They provide easier access to EERE's vast array of technologies and resources to ensure they are part of the economic solutions for communities across the country. Through an integrated information and outreach approach, Gateway Deployment facilitates "one-stop" access to a variety of specialized technical and financial assistance.

3.1 Rebuild America

3.1.1 Target Market

Project Description. Rebuild America accelerates energy efficient improvements in existing buildings through community-level partnerships and focuses on K-12 schools, colleges and universities, State and local governments, public and multifamily housing, and commercial buildings. 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.

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.

Market Size.[2] The primary market is the commercial-building sector, which includes nearly 68 billion square feet of building space; however, the five commercial building types that this project targets make up a total of nearly 32 billion square feet. The public assistance[1] and multifamily housing that this project also targets make up an additional 27 billion square feet.

Baseline technology improvements. For this analysis, PNNL did not suggest any changes in technology improvements apart from the EIA baseline.

3.1.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price.

- Cost of Conventional Technology:[4] Average of \$101/ ft^2 for new commercial and multifamily; \$0 for existing buildings.
- Cost of WIP Technology:[1] \$103.00/ ft^2 for new commercial and multifamily; \$3/ ft^2 (2001 to 2009), increasing to \$4/ ft^2 (2010 to 2030) for existing buildings.
- Incremental Cost: 2% above base for new buildings; \$3/ft^2 (2005 to 2009), increasing to \$4/ ft^2 (2010 to 2030) for existing buildings.

Key Consumer Preference/Values – Nonenergy Benefits.[1] The cost and performance characteristics were used to model this project in NEMS-GPRA05/MARKAL-GPRA05. The following nonenergy characteristics were not considered.

- Revitalized neighborhoods and business districts
- Improving school facilities
- Better low-income housing
- Positive economic impact from keeping dollars locally and increasing property values.

3.1.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets.

Technical Characteristics. The project displaces current design/building practices with the target of reducing heating, cooling, water heating, and lighting energy use in retrofitted and new buildings by 25%/ft^2 in 2005 and 40%/ft^2 by 2010.

Technical Potential. Approximately 5 quadrillion Btu in 2005. Total heating, cooling, water-heating, and lighting primary end use for commercial and residential is 23 QBtu and 14 QBtu, respectively. The targeted building types for commercial only represent about 45% total energy consumed and 15% of the total residential energy consumed. The near-term goal is to reduce energy consumption in the targeted buildings by 40%, thus the potential is: (23QBtu x .45 x .40) + (14QBtu x .15 x .40) = 5 QBtu

Expected Market Uptake. PNNL assumed that this activity would not occur in the absence of DOE funding, therefore, no acceleration of market acceptance was modeled. The penetration into the marketplace was calculated within NEMS-GPRA05, based on the price and performance characteristics.

3.1.4 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 2003.
(3) FY 2003 Data Collection interview with the project manager, Daniel Sze, August 20, 2001.
(4) RS Means Company, Inc. 2002. *"RS MEANS Square Foot Costs"*. 23rd Edition, Kingston, MA.

3.2 Energy Efficiency Information and Outreach

3.2.1 Target Market

Project Description. Energy Efficiency Information and Outreach activities will result in packaged information on appropriate EERE technologies for key market segments, e.g., consumers, homeowners, and school officials.

Market Description. The targeted market segments are primarily existing residential and commercial buildings in all climate zones, with the emphasis in FY 2005 on the residential sector, of which there are approximately 100 million existing household units.(1) The Energy Efficiency Information and Outreach project is a three-pronged effort focused on the funding of Home Performance with Energy Star pilot projects in conjunction with the Environmental Protection Agency (EPA), communication and marketing support for the pilot projects, and for general OWIP communication and outreach focused on a broad range of energy market sectors. The project conceptualizes, plans, and implements a systematic approach to the marketing and communication objectives and evaluation of the projects it supports.

Baseline technology improvements. For this analysis, PNNL did not suggest any changes in technology improvements apart from the EIA baseline.

3.2.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Based on discussions with the program manager, PNNL assumed that the cost of Pilot Projects (the average price per household) would be $5,000—currently, Pilot Project homeowners are spending between $4,000 and $6,000 in retrofits through the Pilot Project program. PNNL assumed that the cost of other outreach activities (the average price per household) would be $1,000, based on discussions with the program manager. In both cases, the cost of conventional technology is $0 because the homeowners are not expected to implement similar activities in the absence of the program.

3.2.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. PNNL's calculations were based on a baseline that was developed from the Energy Information Administration's (EIA's) Commercial Buildings Energy Consumption Survey (CBECS), Residential Energy Consumption Survey (RECS), and the Annual Energy Outlook (AEO). For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[3].

Technical Characteristics. As most of the Pilot Project retrofit measures involve the building shell (e.g., insulation, windows), PNNL assumed that these activities primarily impacted the space-conditioning load of existing buildings. Because these retrofits are occurring because of the programmatic builder certification, marketing efforts, and financing options, PNNL assumed that the activity would reap all benefits associated with the retrofits—about a 20% load reduction in space conditioning. Other outreach activities were based on funded projects such as the Home Energy Saver Web site, where consumers can compare their home's energy use with that of an average home in their area and receive information about possible retrofits for their homes. PNNL assumed that consumers visiting such sites and acting on the information were already planning to perform some energy-efficient retrofits to their household, so PNNL assumed that the average incremental space conditioning and water-heating load reduction would be about 5% (e.g., the homeowner was initially interested in replacing the HVAC system, but when provided additional information about other cost-effective energy-saving measures, decided also to add more insulation to the home).

Expected Market Uptake. The penetration rates for Information Outreach Pilot Projects and Other Outreach Activities were developed using a diffusion model based on Fisher and Pry (1971)[2]. The equation for determining market diffusion over time is:

$$N(t) = \frac{\kappa}{1 + \exp(-\frac{\ln(81)}{\Delta t}(t - t_m))}$$

Where K = Maximum market share potential
t_m = year in which 50% of potential is reached
Δt = time to grow from 10% to 90% of potential (years)

For pilot projects, k=0.0002%, t_m=17, and Δt=20. For Outreach Activities, k=0.004%, t_m=17, and Δt=20. These values were developed through trial and error to achieve the expected annual household impact in 2005 and in "out" years, based on discussions with the program manager. **Table 7** displays the resulting estimated number of homes impacted based on the penetration curve developed.

Table 7. FY 2005 Market Penetration for Information Outreach Projects

Year	Annual No. Homes – Pilot Projects	Annual No. Homes – Outreach Activities
2005	231	4,620
2006	569	11,383
2007	700	13,998
2008	859	17,184
2009	1,052	21,039
2010	1,284	25,684
2011	1,562	31,240
2012	1,891	37,828
2013	2,279	45,574
2014	2,729	54,573
2015	3,245	64,891
2016	3,828	76,550
2017	4,474	89,478
2018	5,177	103,546
2019	5,927	118,549
2020	6,709	134,175
2021	7,503	150,060
2022	8,291	165,814
2023	9,053	181,051
2024	9,771	195,428
2025	10,434	208,671
2026	11,031	220,620
2027	11,557	231,149
2028	12,010	240,205
2029	12,395	247,896
2030	12,714	254,283

The pilot project activity was assumed not to occur without DOE funding, because it allocates money for builder training and certification, program marketing support, and program-specific financing options; therefore, no acceleration of market acceptance was modeled. Other outreach activities were modeled as an incremental load reduction, above what the homeowner would have done in the absence of the information.

3.2.4 Sources

(1) Discussions with Kyle Andrews, Project Manager, August/September 2003.
(2) Fisher, J.C., and R.H. Pry, (1971) "A Simple Substitution Model of Technological Change." Technological Forecasting and Social Change, 3, 75-88.
(3) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

3.3 Building Codes Training and Assistance

3.3.1 Target Market

Project Description. Building Codes Training and Assistance will provide technical and financial assistance to States to update and implement their energy codes and train approximately 2,000 code officials, designers, and builders to implement these codes. The program will work with three-five pilot States, builder organizations, and financial institutions to provide a package combining builder training, Energy Star promotion, and financing for new and existing homes.

Market Description. The market includes new residential low-rise buildings three stories or less in height, new commercial and multifamily high-rise buildings, and all additions and renovations to buildings requiring code permits.

Size of Market. The commercial market size is about 2 billion ft^2 of new commercial floor space added each year. The Federal sector represents nearly 2.3% overall of new commercial-building construction. Additionally, each year about 1.4 million residential building permits are issued, of which 1 million are 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, based on information gathered from state and regional offices by the Building Codes Assistance Program (BCAP). Also, consumers spend approximately 45[b] billion dollars a year on remodeling and renovating projects in private residences, about half of which could potentially be covered by an energy code. One market not covered by codes is manufactured homes, which fall under Housing and Urban Development (HUD) jurisdiction and regulations.

Baseline Technology Improvements. Initial compliance with new codes was assumed to be lower in the base case, i.e., without the Building Energy Codes Project (BECP) than with BECP. Compliance in this context is measured as the percentage of potential savings from the existing code to the updated code. For FY05, the percentage of potential savings, in the first year of the single future code, was assumed to be approximately 20% for envelope measures and 30% for lighting measures without BECP. Ten years after adoption, compliance rates are assumed to increase to 50% for envelope and 60% for lighting. The impact of these compliance percentages varies by state. Some states are assumed to update from the ASHRAE 90.1-1989 standard; others from the ASHRAE 90.1-1999 standard.

3.3.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. Incremental investment costs were developed assuming a five-year payback period on investment (i.e., an annual energy cost savings of $1 implies an initial investment of $5). These

[b] U.S. Census Bureau (Census). 2000. "1997 Economic Census Construction Geographic Area Series." U.S. Department of Commerce, March 2000. Washington D.C. Located at the following website: http://www.census.gov/epcd/www/97EC23.HTM

estimates were based on a series of benefit-cost studies that examined the energy savings and first-cost impacts of code improvements on seven building prototypes[c].

Key Consumer Preferences/Values. The following nonenergy characteristics were not considered.

- Improved environment and more comfortable buildings.
- Lower utility bills
- Fewer home-maintenance and repair activities
- Reduced pollution due to the reduced burning of fossil fuels and electricity generation, which improves air quality and mitigates the negative impacts of global warming.

3.3.3 Methodology and Calculations

Inputs to Base Case. PNNL did not provide inputs to change the base case assumptions for the program markets. With respect to codes, it is indeterminate as to whether potential future code improvements are incorporated into the NEMS-GPRA05 base case. The NEMS-GPRA05 base case does include some improvements to the building shell efficiency; however, the basis for these improvements (e.g., general building practice improvements, changes in codes requirements, improvements in materials) is not specified by EIA. Codes that have been issued—but that have not gone into effect—may be included in the NEMS-GPRA05 base case, but would not be included in the GPRA forecast of savings for that activity, because it would no longer be funded. Only an estimate of potential future codes is included in the GPRA estimates. For more information about the methodology used by PNNL, see *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (2004)[(7)].

Technical Characteristics: Commercial Buildings. Energy savings from this project result from some basic improvements in the overall energy efficiency of commercial buildings. The present funding for conducting research activities to establish the cost-effective levels of energy codes for new commercial and multifamily high-rise buildings is through the Commercial Buildings Integration subprogram within the Building Technologies Program (BT). The WIP Building Codes Training and Assistance project funds the development of core materials (such as compliance tools and training materials) and provision of training and financial and technical assistance for states to update and implement their building energy codes. Benefits cannot be clearly allocated to either project; thus, the benefits estimated are a function of both training and deployment as well as development of the commercial building energy codes and standards, and the resultant benefits are then allocated between WIP and BT.

Savings estimates for commercial codes are based on increased compliance and accelerated adoption from the ASHRAE 90.1-2004 code and the "next" code assumed to be published in 2007. For FY05, future codes (up through 2010) are assumed to achieve a potential reduction of 18% in electricity and a 10% reduction in natural gas, compared to 90.1-1999. The WIP-funded activities are assumed to increase the initial compliance with these codes to approximately 70% for envelope requirements and 80% for lighting requirements. Adoption is accelerated in the range of five to 10 years, depending on the historical experience with building codes on each

[c] Further information on the series of reports can be found at the Building Energy Codes Web site: http://www.energycodes.gov/implement/tech_assist_reports.stm.

state. Barring future guidance from DOE, benefits for FY 2005 were assumed to be allocated based on the ratio of actual funding levels.

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 (conducted by the Building Technologies Program) 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"(1)
- Upgrading 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"(2)
- Upgrading the International Energy Conservation Code (IECC).(3)

The FY 2005 GPRA estimates are based on increased compliance with existing codes, accelerated adoption of the 1999 and 2002 editions of ASHRAE 90.1-1999(4) 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 among the ASHRAE 90.1-1989, 90.1-1999, and 90.1-2002(5) 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[6]), the average reduction in site energy use was estimated to be about 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. Successful state adoption of 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, increasing to 66% without the project and 79% by 2010 with the project.

The compliance with 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 about 27% at the time of adoption, increasing to 31% without the project and 73% with the project after the first 10 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.

Expected Market Uptake: Commercial Buildings. As part of work for an internal analysis of the historical impacts of the Building Codes project in August 2003, the assumptions regarding the acceleration effect of the program were modified (e.g., program activities leading to states adopting codes more rapidly than they would have otherwise). In general, the states were classified into groups that: 1) immediately adopted the ASHRAE 90.1-1989 code, 2) would have adopted within five years without the project, or 3) would have adopted within 10 years without the project. These time periods were then reduced by one year for each successive code after the 1989 code. (Thus, for example, a five-year lag for 90.1-1989 is assumed to fall to three years for the forthcoming ASHRAE 90.1-2004 code). The overall impact of this change was to increase the average lag between the publication of a new standard and when it is adopted—without the Building Codes project. This modified set of assumptions increases the overall estimate of the future energy savings impact from the program.

Technical Characteristics: Residential Buildings. The FY 2005 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. This discussion 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 about 15%. This requirement increases the heating load by a small amount, about 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.

Expected Market Uptake: Residential Buildings. 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 increased familiarity with the codes, 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, increasing to 49% without the project and 72% by 2010 with the project.

The compliance with 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 time frame, the standard's greater stringency will result in somewhat lower compliance. Initial compliance was assumed to be about 30% at the time of adoption, increasing to 31% without the project and 73% with the project after the first 10 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.

3.3.4 Sources

(1) 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.
(2) 10 CFR 434, "Energy Code for New Federal Commercial and Multi-Family High Rise Residential Buildings," *Code of Federal Regulations*, as amended.
(3) International Energy Conservation Code. 2003. International Code Council, Falls Church, Virginia.
(4) ASHRAE/IES Standard 90.1-1999, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(5) ASHRAE/IES Standard 90.1-2002, "Energy Standard for Buildings Except Low-Rise Residential Buildings," American Society of Heating, Refrigeration, and Air-Conditioning Engineers.
(6) 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
(7) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

3.4 Energy Star

3.4.1 General Target Market

Project Description. Energy Star was introduced by the Environmental Protection Agency in 1992 as a voluntary labeling program designed to identify and promote energy efficient products, with the goal of reducing carbon dioxide emissions. Through its partnership with more than 7,000 private and public sector organizations, Energy Star delivers the technical information and tools that organizations and consumers need to choose energy-efficient solutions and best management practices.

Market Description. The market is determined by the project equipment. For FY 2005, the following residential equipment is characterized:

- Clothes washers
- Refrigerators
- Electric water heaters
- Gas water heaters
- Room air conditioners
- Dishwashers
- Compact Fluorescent Lamps (CFLs)
- Windows

Baseline technology improvements. For this analysis, PNNL did not suggest any changes in technology improvements.

3.4.2 Key Factors in Shaping Market Adoption of EERE Technologies

Key Consumer Preferences/Values and Manufacturing Factors. The following nonenergy characteristics were not considered.

- Increased comfort for residential homeowners
- Decreased time spent changing 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.

3.4.3 General Methodology

Market transformation projects, such as Energy Star, attempt to accelerate market penetration of existing high-efficiency technologies. The information provided by these programs is designed to influence the consumer's awareness of future energy cost savings as compared to the initial cost of the technology. From a modeling standpoint, these efforts are assumed to be represented by a reduction in the consumer's implicit discount rate or hurdle rate. The implicit discount rate for a technology significantly impacts how a consumer determines the present value of the benefits and costs associated with this technology, because it is assumed to capture the perceived risk in the purchase of new products. 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. If the implicit 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 – reflecting the consumer's uncertainty about future benefits. Therefore, to facilitate project modeling, one goal of the Energy Star project is to reduce implicit discount rates by providing additional information about the potential benefits to the consumer.

Within NEMS-PNNL[d], the two modeling parameters determining the implicit discount rate are labeled Beta1 and Beta2[(10)]. 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 more than 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

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

reducing the Beta1 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.

General Expected Market Uptake. PNNL modeled clothes washers, refrigerators, electric water heaters, gas water heaters, room air conditioners, and dishwashers 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.

3.4.4 Clothes Washers

3.4.4.1 Target Market

Market Description. This project targets new clothes-washer sales.

3.4.4.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. 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 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 [11] suggests that 80% to 90% of the energy consumption of clothes washers is attributable to water heating. **Table 8** shows the original and revised NEMS-PNNL inputs for clothes washers.

Expected Market Uptake. 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 9** shows the market share results of the NEMS-PNNL model runs for clothes washers.

Table 8. Original NEMS and Revised NEMS-PNNL Inputs for Energy Star Clothes Washers

Technology	Start Yr	End Yr	Water Coeff.	Energy Factor	Installed Cost ($)	Type
Original NEMS Inputs						
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 9. 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.				

3.4.5 Refrigerators

3.4.5.1 Target Market

Market Description. This project targets new refrigerator sales.

3.4.5.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. 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.

As part of the EIA forecast, the 2001 standard (Model 1) was assumed to yield no increase in cost. **Table 10** 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 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 the shaded columns in the table below.

Table 10. Refrigerator Efficiency and Costs: *Annual Energy Outlook 2001*

Model	Initial Year	Ending Year	Annual Consumption (kWh)	Installed Cost ($1998)	Retail Cost ($1998)	Modified NEMS-PNNL Inputs	
						Installed Cost ($1998)	Retail Cost ($1998)
1	1997	2001	690	530.0	480.0	530.0	480.0
1	2002	2020	478	530.0	480.0	580.0	480.0
2	1997	2001	660	550.0	500.0	550.0	500.0
2	2002	2020	460	550.0	500.0	600.0	550.0
3	1993	2001	518	850.0	800.0	850.0	800.0
3	2002	2020	460	550.0	500.0	600.0	550.0
3	2005	2020	400	700.0	650.0	700.0	650.0
4	1993	2001	843	1313.8	1313.8	1313.8	1313.8
4	2002	2020	577	1313.8	1313.8	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, which 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 nearly $270. A more cost-effective unit would consume 1.16 kWh/day (423 kWh/yr) at a projected cost increase of $106.

Based on 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 of the ADL report) 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 kWh/day to 400 kWh/day) between models 2 and 3 could be achieved for $100 or less.

Expected Market Uptake. The *Annual Energy Outlook 2001*(2) baseline parameters that determined the market share for high-efficiency refrigerators are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0229}{-0.1207} \approx \textit{implicit discount rate} = 19\%$$

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:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0055}{-0.1207} \approx \textit{implicit discount rate}^{E-Star} = 5\%$$

The resulting NEMS-PNNL market shares for Energy Star refrigerators for 2005 and 2010 are shown in **Table 11**.

Table 11. Energy Star Project – Refrigerators (NEMS-PNNL 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

3.4.6 Electric Water Heaters

3.4.6.1 Target Market

Market Description. This project targets sales of new electric water heaters.

3.4.6.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. **Table 12** 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 12. Key NEMS 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 with efficiencies exceeding 0.9. As **Table 12** 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.

Expected Market Uptake. The *Annual Energy Outlook 2001*[(2)] baseline parameters that determined the market share for high-efficiency water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.01619}{-0.01952} \approx implicit\ discount\ rate = 83\%$$

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:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0082}{-0.01952} \approx implicit\ discount\ rate^{E-Star} = 42\%$$

Table 13 shows the specific NEMS-PNNL market share results.

Table 13. 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.				

3.4.7 Gas Water Heaters

3.4.7.1 Target Market

Market Description. This project targets sales of new gas water heaters.

3.4.7.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. Table 14 shows EIA's key NEMS inputs for the *Annual Energy Outlook 2001*.(2) The Energy Star project was assumed to promote high-efficiency gas water heaters with energy factors of 0.6 or higher. As Table B-8.8 (in AEO 2001) 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.

Table 14. Key NEMS 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

Expected Market Uptake. The *Annual Energy Outlook 2001*(2) baseline parameters that determined the market share for high-efficiency gas water heaters are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.05393}{-0.1136} \approx implicit\ discount\ rate = 47\%$$

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:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0323}{-0.1136} \approx implicit\ discount\ rate^{E-Star} = 28\%$$

Table 15 shows the specific NEMS-PNNL market-share results.

Table 15. 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

3.4.8 Room Air Conditioners

3.4.8.1 Target Market

Market Description. This project targets sales of new room air conditioners.

3.4.8.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. For 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 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 16** shows both the original NEMS input data and the revised NEMS-PNNL 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 less than 1%. The split in market share between the lowest and intermediate efficiency unit (COP = 2.83 and 3.11, respectively) was generally about 75%/25% in favor of the lowest-efficiency model.

Table 16. 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.					

Expected Market Uptake. The *Annual Energy Outlook 2001*[(2)] baseline parameters that determined the market share for high-efficiency room air conditioners are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.0170}{-0.0120} \approx implicit\ discount\ rate > 100\%$$

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:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.0070}{-0.0120} \approx implicit\ discount\ rate^{E-Star} = 58\%$$

Table 17 shows the specific NEMS-PNNL market share results for the high-efficiency model.

Table 17. NEMS-PNNL Results for Energy Star Room Air Conditioners (national 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

3.4.9 Dishwashers

3.4.9.1 Target Market

Market Description. This project targets sales of new dishwashers.

3.4.9.2 Methodology and Calculations

Inputs to Base Case and Technical Characteristics. The NEMS baseline (*Annual Energy Outlook 2001*)[(2)] data input for 2005 shows three dishwashers, with energy factors 0.46, 0.59, and 0.71. **Table 18** 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 18. Key NEMS 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

Expected Market Uptake. The *Annual Energy Outlook 2001*[(2)] baseline parameters that determined the market share for high-efficiency dishwashers are described as follows:

$$\frac{Beta_1}{Beta_2} = \frac{-0.02738}{-0.02413} \approx implicit\ discount\ rate > 100\%$$

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:

$$\frac{Beta_1^{E-Star}}{Beta_2^{E-Star}} = \frac{-0.01338}{-0.02413} \approx implicit\ discount\ rate^{E-Star} = 55\%$$

Table 19 shows the specific NEMS-PNNL market share results for the two high-efficiency models.

Table 19. NEMS-PNNL Results for 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.

3.4.10 Energy Star CFLs

3.4.10.1 Target Market

Market Description. The target market for this technology is residential non-can and non-R-Lamp Edison socket lights, which would not otherwise switch to Compact Fluorescent Lamps (CFLs). Analysis of Energy Star CFLs was based on the program's stated goal of converting 20% of the residential incandescent installed based to high-quality, high-efficiency, ENERGY STAR CFLs.

3.4.10.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. PNNL assumed that the cost of the conventional incandescent technology is $0.75. The cost of the ENERGY STAR CFL is assumed by PNNL to decrease over the study period from approximately $5 per CFL in 2004 to $3 per CFL in 2030.

Baseline market acceptance. In 1998, PNNL conducted a study examining the historical market penetration for 10 energy-efficient products related to the buildings sector. The results of this study are documented in the PNNL report, *Methodological Framework for Analysis of GPRA Metrics: Application to FY04 Projects in BT and WIP* (2003, PNNL-14231). The resulting data were used to develop a set of generic diffusion curves. These curves were used to generate market penetration estimates for projects that do not have a forecast of annual sales targets. For the Energy Star CFL activity, the lighting diffusion curve was used.

3.4.10.3 Methodology and Calculations

Technical Characteristics. Energy Star-qualified CFLs have the efficacies(6) shown in **Table 20.**

Table 20. Compact Fluorescent Lamp Efficacies

Lamp Power (Watts) & Configuration	Minimum Efficacy: Lumens/watt (Based upon initial lumen data)
Bare Lamp:	
Lamp power < 15	45
Lamp power >= 15	60
Covered lamp (no reflector):	
Lamp power <15	40
15 >= lamp power < 19	48
19 >= lamp power < 25	50
Lamp power <= 25	55
Reflector Lamp:	
Lamp power < 20	33
Lamp power >= 20	40

Modeling is based on the bare lamp, because reflector lamps represent only about 6% of the shipments of large incandescent lamps, and covered lamps are only a small fraction of the total CFL market. CFLs of 15W and greater can replace incandescent lamps at 75W and above, and were assumed to have an efficacy of 60 lumens/watt. Less than 15W CFLs can replace incandescent of less than 75W and were assumed to have an efficacy of 45 lumens/watt. About 58% of incandescent lamps in homes have wattages less than 75W and 42% of incandescent lamps in homes have wattages 75W and greater(7). The resultant weighted average lumens/Watt for Energy Star CFLs is 51.3 lumens/Watt.

Expected Market Uptake. PNNL assumed that by 2020, in the residential sector, ENERGY STAR CFLs would capture 6.16% of non-can and non-R-lamp incandescent sales (i.e., sales for non-can and non-R-lamp Edison sockets that would not have otherwise converted to CFLs). The 6.16% is based on a market penetration goal of capturing 20% of the installed base. Energy Star CFLs were assumed to penetrate both 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), and the low-use part of the market. Energy Star CFLs were assumed to be put in high-use applications 70% of the time. The sockets in high-use areas (28.4% of the total sockets) will use roughly the same fraction of the lamps (i.e., 28.4% of the sockets consume 76.4% of the lighting energy use). A sales fraction of 6.16% will yield a long-term installed base of 20% of all sockets with 70% of the Energy Star CFLs in high-use sockets and 30% in low-use sockets—i.e., the A-line incandescents that would be present without the Energy Star program. Penetration curves were developed based on market diffusion curves developed by PNNL and documented in the 2004 PNNL report, *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (Elliott, et. al) (see **Figure 1**)[e].

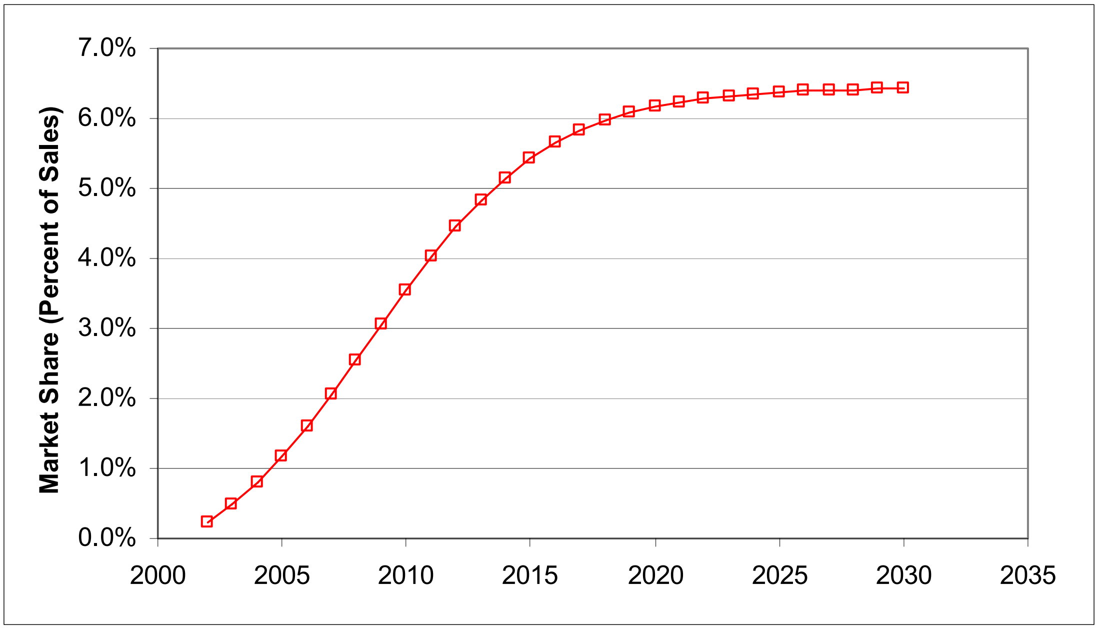

Figure 1. Actual Energy Star CFLs Market Penetration Curve – Percent of Sales to Non-Can, Non-R-Lamp, Incandescents

3.4.11 Windows

3.4.11.1 Target Market

Market Introduction. The technology is commercially available. PNNL assumed that this project would accelerate the penetration in the marketplace by 10 years.

3.4.11.2 Methodology and Calculations

Performance Parameters: Performance parameters are listed in **Table 21**.

Table 21. Performance Parameters for Low-e Windows

Parameter	Value	Units
Shading Coefficient	0.52	Dimensionless
U-value	0.357	$Btu/h \bullet ft^2 \bullet {}^oF$

[e] The ENERGY STAR CFLs are assumed to compete only against incandescents (not all Edison sockets). Hence, given that 4.0% of the Edison sockets are already CFLs by 2005 and that it is expected that by 2020 this will increase to 11% without ENERGY STAR, the penetration against incandescents only is somewhat higher than the penetration against all Edison sockets. This curve compensates for the declining incandescent share of the Edison socket market such that the 20% (of all non-can and non-R-lamp Edison sockets that would not have otherwise converted to CFLs) installed base can be achieved.

Performance Target: Performance characteristics vary by building type and climate zone. The estimated savings per building were determined by simulating residential buildings in all climate zones. National impacts were determined using BEAMS (see **Table 22**).

Table 22. Performance Targets for Low-e Windows

	New Buildings		Existing Buildings	
	Heat		Heat	
	North	South	North	South
Single Family	39.73%	66.19%	28.22%	42.54%
Multi Family	75.26%	94.44%	63.73%	84.21%
Mobile Home	44.99%	53.89%	34.16%	39.30%
Assembly	44.88%	76.06%	38.32%	64.07%
Education	41.27%	73.62%	45.36%	66.11%
Food Sales	64.06%	91.69%	59.00%	76.73%
Food Service	66.17%	90.08%	56.17%	80.10%
Health Care	97.69%	99.81%	91.42%	98.22%
Lodging	63.34%	95.42%	55.83%	88.91%
Office-Large	65.00%	85.55%	59.44%	82.17%
Office-Small	50.17%	73.83%	43.72%	72.34%
Merc/Service	57.53%	80.16%	58.11%	75.68%
Warehouse	53.33%	63.84%	14.82%	9.86%
Other	55.83%	86.76%	44.19%	59.20%

	New Buildings		Existing Buildings	
	Cool		Cool	
	North	South	North	South
Single Family	13.95%	16.59%	16.30%	17.38%
Multi Family	1.92%	9.23%	7.35%	11.80%
Mobile Home	22.31%	23.04%	19.26%	19.68%
Assembly	-11.69%	-8.47%	-4.85%	-4.18%
Education	-23.64%	-15.70%	-8.81%	-4.87%
Food Sales	-13.76%	-11.35%	-11.59%	-6.65%
Food Service	-15.38%	-10.65%	-8.14%	-6.10%
Health Care	-21.81%	-12.28%	-19.93%	-13.88%
Lodging	-38.61%	-29.58%	-18.52%	-19.56%
Office-Large	-40.67%	-31.12%	-33.71%	-27.50%
Office-Small	-25.43%	-23.59%	-7.03%	-10.92%
Merc/Service	-24.41%	-17.66%	-17.90%	-10.77%
Warehouse	63.97%	21.01%	47.73%	2.10%

Installed Cost:—Incremental Cost Over Conventional Double-Pane Windows

- 2005: $1.00/ft^2
- 2010: $0.50/ft^2
- 2015: $0.00/ft^2

Expected Market Uptake. The purpose of the program is to increase the penetration of low-e glass from 40% in the residential market and 10% in the commercial market to 100% in both markets by 2020. Both programs, Low-e Market Acceptance and Energy Star Windows (Office of Weatherization and Intergovernmental Programs), form the joint means to achieving the low-e penetration goal – the savings are to be split equally. Penetration curves were developed based on market diffusion curves developed by PNNL and documented in the 2004 PNNL report, *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort* (Elliott, et. al). The "Accelerated" penetration curve represents the percent of superwindow sales with the DOE project; the "Net" penetration curve represents the percent of sales attributable to DOE, as PNNL assumed that the DOE project would accelerate market acceptance by 10 years. The penetration rates are shown in **Figures 2 and 3**. For Low-e Market Acceptance/Energy Star Windows, PNNL assumed that these projects would accelerate the acceptance of this technology in the marketplace by 10 years.

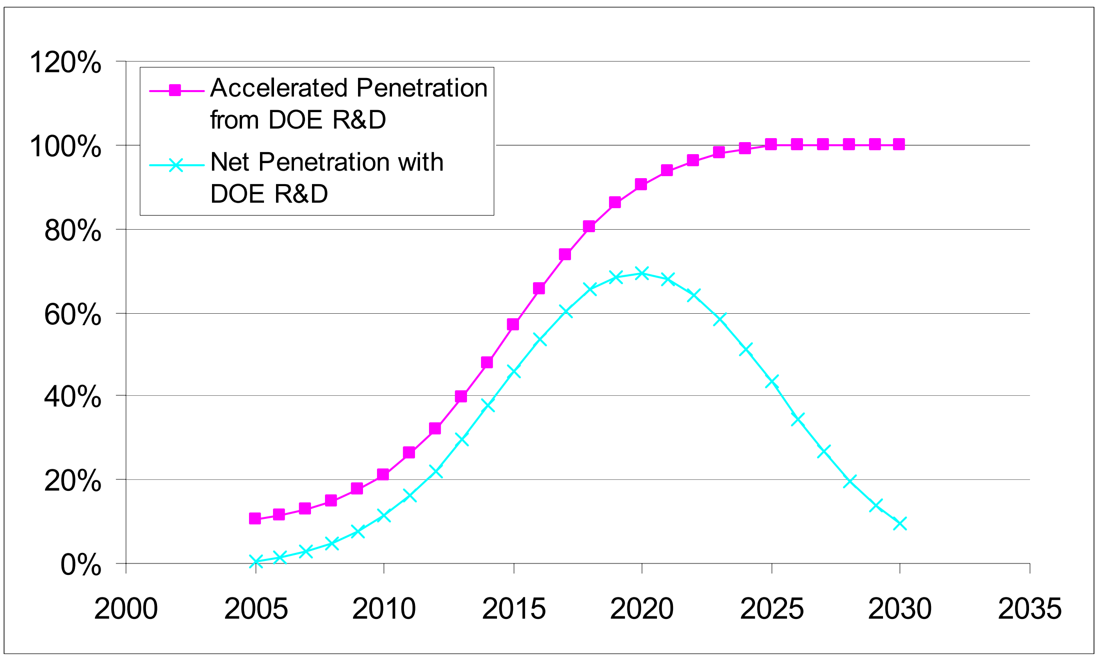

Figure 2. FY05 Low-e Windows – Commercial Buildings Percent of Sales

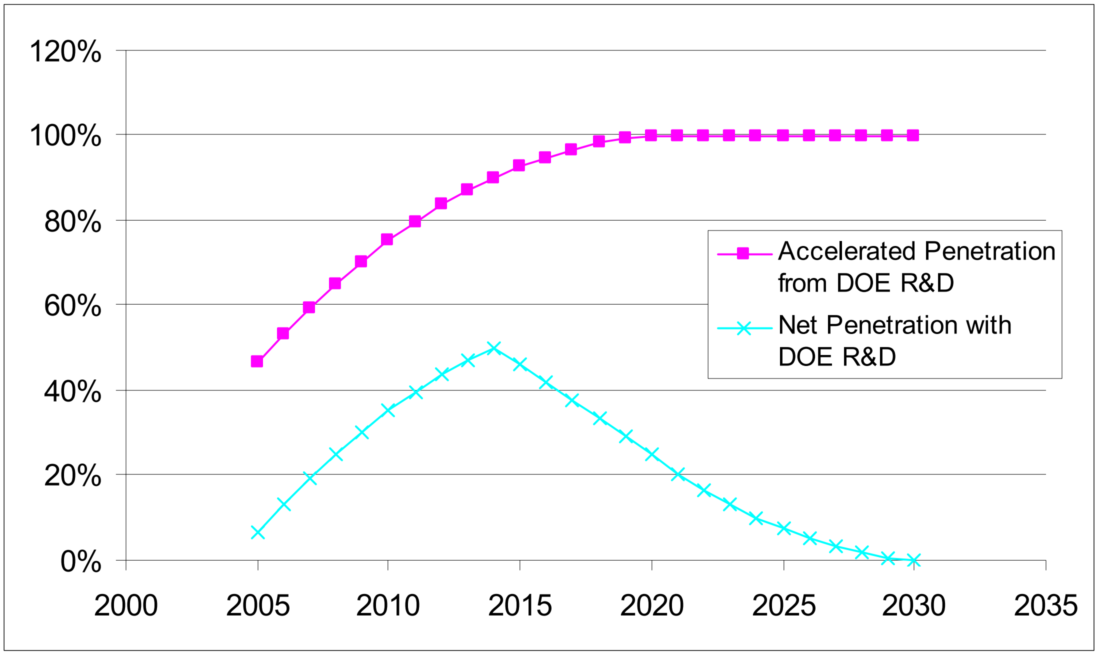

Figure 3. FY05 Low-e Windows – Residential Buildings Percent of Sales

3.4.12 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.
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(11) "Clothes Washer Technical Support Document" source: www.eere.energy.gov/buildings/appliance_standards/residential/clwash_0900_r.html.
(12) Elliott, D.B., D.M. Anderson, D.B. Belzer, K.A. Cort, J.A. Dirks, D.J. Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: The GPRA Metrics Effort*. PNNL-14697. Pacific Northwest National Laboratory, Richland, Washington.

3.5 Clean Cities

3.5.1 Target Market

Project Description. Clean Cities supports public-private partnerships that deploy alternative fuel vehicles and build supporting infrastructure. Clean Cities works with local businesses and governments to guide them through the process, including goal setting, coalition building, and securing commitments.

Market segment. Clean Cities seeks to displace current conventional gasoline and diesel vehicles with alternative-fuel vehicles and advanced vehicle technologies. It also develops the refueling infrastructure for Alternative Fuel Vehicles (AFVs).

Market size. The total light-vehicle stock is 215 million, including trucks in the Commercial 2B classification. Of the total stock, 17.4 million are fleet vehicles, including Commercial 2B trucks. The Clean Cities Program works largely with fleet managers and buyers, rather than targeting all private consumers, because of the challenges related to building fueling infrastructure. The market for the Clean Cities Program also includes heavy-duty vehicles, such as trucks and buses.

Base case growth: For purposes of an estimate of the number of AFVs attributable to Clean Cities, exogenous to NEMS-GPRA05 modeling, the activity in the alternative-fuel vehicle market was assumed to be very low. In the absence of the Clean Cities Program, the number of AFVs was assumed to grow at 1% per year. The NEMS-GPRA05 base case growth was not changed.

Consistency with EERE baseline: The EERE baseline was used for Clean Cities NEMS-GPRA05 modeling. The exogenous calculations to determine a number of vehicles attributable to the Clean Cities program use a different baseline. For purposes of calculating the number of AFVs attributable to Clean Cities, an AFV growth rate of 1% was assumed to occur in the absence of a Clean Cities program. This was based on expert judgment in consultation with Clean Cities DOE staff, Clean Cities lab analysts, and the Office of Planning, Budget, and Analysis (PBA). This assumption may be compared with the regulatory requirement of EPAct, and with historical growth rates in areas that lack Clean Cities programs. DOE has estimated that the EPAct regulatory requirement results in purchases of approximately 30,000 AFVs per year[f], or about 0.2% of light-duty vehicle sales. However, AEO2003 shows a 10% growth in light-duty AFVs stock between 2000 and 2025. This high level of AFVs in AEO2003 is driven by EPAct regulatory targets that may be higher than expected market performance. Revising this baseline was considered for GPRA FY05, but was not performed because a proposed alternative baseline was not identified.[g] According to the EIA data used for GPRA FY05, non-Clean Cities showed a 2.7% growth rate in numbers of AFVs between 1992 and 2001, so a baseline less than that value is a logical assumption.

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[f] U.S. Department of Energy (2001). "EPAct Fleet Information and Regulations Fact Sheet," DOE/GO-102001-1306, April 2001. Accessed at www.ott.doe.gov/ott/pdf/what_is_epact.pdf. DOE estimates that the EPAct regulatory requirement cause purchases of 20,000-25,000 AFVs per year, according to FR Vol 68, No 42, March 4, 2003, page 10326, "Office of Energy Efficiency and Renewable Energy; Alternative Fuel Transportation Program; Private and Local Government Fleet Determination: Notice of Proposed Rulemaking" Accessed online at www.afdc.doe.gov/pdfs/fr_notice_nopr.pdf.

[g] Personal communication, John Holte, OnLocation. January 22, 2004.

Baseline technology improvements. For this analysis, NREL did not suggest any changes in technology improvements.

Baseline market acceptance. The literature on consumer choice of vehicle technologies has not been reviewed for this project. DOE has developed a variety of detailed models of consumer choice of vehicles. These models include factors such as cost, performance, fuel availability, and other attributes of vehicles that are generally disadvantageous to AFVs. They are not useful for assessing market penetration of technologies whose advantages are primarily environmental, macroeconomic, and national security, such as AFVs. Data such as consumer discount rates have been reported in that literature with regard to vehicle technologies and fuel savings, although there is less specific research on AFVs. For purposes of the Clean Cities baseline market acceptance, no changes were recommended to the NEMS-GPRA05 baseline to reflect these market-acceptance issues. For purposes of calculating the number of AFV sales attributable to Clean Cities, it was assumed that the number of AFVs would increase by 1% per year in the absence of the program.

3.5.2 Key Factors in Shaping Market Adoption of EERE Technologies

Price. AFVs are assumed to cost more than equivalent conventional vehicles throughout the forecast period. Using AEO 2003 estimates, typical price increments for light-duty vehicles are approximately $2,000 for E85 vehicles, $6,000 for CNG vehicles, and $5,000-$6,000 for LPG vehicles. Break-even points vary depending on vehicle, fuel, duty cycle, subsidies, and discount rate. Break-even timing is highly sensitive to fuel-input price. Incremental costs of heavy-duty vehicle technologies were not identified in AEO 2003 data tables. For buses, one source suggests typical incremental vehicle costs of about $20,000-$40,000[h]. Per-mile relative vehicle costs have also been estimated in some studies, and these are highly sensitive to fuel cost and other assumptions.

Key consumer preferences/values. Vehicle-purchase decisions depend on a large number of preferences and values. Many of these are represented in the Transportation Sector Model of NEMS[i]. Some AFV features that may be especially important include:

1. Emissions performance.
2. Type or origin of fuel.
3. Vehicle performance and reliability.
4. Ease and safety of fueling.
5. Ease of maintenance.
6. Regulatory requirements on purchaser.

Of these, consumer preference for emissions performance and fuel origin do not appear to be included in the Transportation Sector Model as consumer values, but are included as regulatory effects on vehicle sales.

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[h] General Accounting Office (1999). Mass Transit: Use of Alternative Fuels in Transit Buses. GAO/RCED-00-18. December 1999.

[i] U.S. DOE (2003). "The Transportation Sector Model of the National Energy Modeling System: Model Documentation Report." DOE/EIA-M070(2003). Accessed online at www.eia.doe.gov.

None of these factors were used in estimating the effects of Clean Cities on vehicle purchases exogenous of NEMS-GPRA05.

Manufacturing factors. Manufacturer decisions strongly influence availability of AFVs, and depend on factors such as:

1. Anticipated market size, influenced by extent of fueling infrastructure.
2. Expected vehicle price.
3. Estimated manufacturing costs.
4. Maintenance and warranty issues for manufacturer.
5. Availability of competing investment opportunities.
6. Regulatory requirements on manufacturer.

Some manufacturing factors are included in NEMS, though not at this level of detail. None of these factors were explicitly considered in developing the estimates of vehicle sales attributable to Clean Cities. In addition to vehicle price, NEMS uses maintenance costs, fuel costs, luggage space, fuel economy, range, acceleration, etc. as vehicle attributes in which consumers are interested.

Policy factors. Policy factors are a significant consideration that influences AFV markets, including:

1. EPAct (1992) AFV purchase requirements.
2. EPA vehicle-emissions requirements.
3. Ethanol tax incentives.
4. AFV purchase incentives/rebates.

3.5.3 Methodology and Calculations

Inputs to Base Case. Clean Cities did not provide inputs to change the base case assumptions for the program markets.

Technical characteristics. The technical characteristics of alternative fuels and vehicles were not changed.

Technical potential. The technical potential of AFVs is very large. There is no barrier in vehicle technology that prevents AFVs from capturing 100% of the highway vehicle market. Indeed, vehicles operating on nonpetroleum fuels (electricity, ethanol) were developed early in the history of the motorized vehicle. Based on a vintaging calculation, if modern AFVs had been available and immediately adopted into the market 15 years ago, then market penetration would now be at 70% for automobiles and 68% for trucks, and 85% of all vehicle miles.[j] Assuming that this would displace all petroleum use in heavy-duty vehicles (because the AFVs in that sector use mostly LPG and CNG) and 80% of the petroleum use in light-duty vehicles (because the AFVs in that sector would mostly use E85, which is 80% ethanol by energy content), then AFVs

[j] Davis, S.C; S.W. Diegel (2003). Transportation Energy Data Book: Edition 23. Oak Ridge National Laboratory. ORNL-6970, Tables 3.6 and 3.6.

today would displace 70% of petroleum use in highway vehicles, or about 8 million barrels of petroleum per day.

This sort of estimate does not consider that modern AFVs were not instantaneously available 15 years ago, nor does it factor in very important barriers such as fuel resources, production, and distribution or in vehicle manufacturing. For example, vehicle-manufacturer preference for large-volume production of a single vehicle type has been described, and some estimates of fuel resources and fuel production capacity have been made.

Expected market uptake. In the AEO base case, AFV market penetration is calculated based on the Transportation Sector Model. In the Clean Cities case for FY05 GPRA, additional AFVs attributable to Clean Cities were assumed to replace conventional vehicles, and this revised vehicle population was modeled. The calculation of additional AFVs attributed to Clean Cities is based on historical experience with the effect of Clean Cities on AFV markets, and also on a survey of Clean Cities coordinators to establish their expectations about future program effects.[k] The historical record shows that Clean Cities has been able to achieve growth in the population of AFVs in any given urban area of roughly 5%-18%, while areas not under the Clean Cities program achieved 2.9 percent growth. In a survey, Clean Cities coordinators estimated anticipated market growth at about 8%.

For GPRA FY05, it was assumed that a Clean Cities program would result in an 8% growth rate in AFVs in Clean Cities (starting in 2006)[l] and a 2.9% growth rate (the historic growth rate for 1992-2001) in AFVs in non-Clean Cities (starting in 2004)[m,n]. Eight percent for Clean Cities was selected because it is within the historical range, expectations of Clean Cities coordinators, and aligns with the program funding assumptions for GPRA. The non-Clean Cities growth rate extends the historical rate. NREL assumed that if the program had never existed, AFVs would have experienced a 1% growth rate starting from 1995.[o] In effect, it is assumed that the Clean Cities program began to have an influence on non-Clean Cities growth starting in 1996. This is based on the idea that some of the historical growth in non-Clean Cities may be attributed to Clean Cities, because of the program's impact on the broader market. The difference in number of vehicles between these two cases was used to calculate Clean Cities attributable vehicle stock and annual sales numbers, which provided the input to the NEMS-GPRA05 modeling run.[p]

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[k] Personal Communication, Elyse Steiner, formerly of NREL, January 29, 2004, describing survey by QSS.

[l] Please see spreadsheet, CleanCityInput\Stocks and Flows\column D

[m] Please see spreadsheet, CleanCityInput\Stocks and Flows\column C

[n] The rationale for the numbers that are used for Clean Cities for 2001-2005 is not fully established at this time. The number for 2001(130,000) appears to round off the historical number (133,046). The numbers for 2002-2005 appear to be based on annual program targets for FY03, FY04, and FY05. The numbers for Total AFVs in use for 1999-2001 use data from EIA that was subsequently revised, and the total AFV numbers for 2002-2003 are derived from the historical growth rate between 1998 and 2001.

[o] Please see spreadsheet, CleanCityInput\Stocks and Flows\column E.

[p] Please see spreadsheet, CleanCityInput. This spreadsheet was obtained from John Holte, OnLocation, on January 15, 2004, as a file named CleanCityInputsElyse.

3.6 Inventions and Innovation

The Inventions and Innovation Program (I&I) is a program mandated by Congress to help inventors and very small businesses develop energy-saving technologies. Historically, I&I accepts proposals in two categories. Category 1 proposals are for concept development and have a $40K maximum grant. Category 2 proposals are for prototype testing and further technical development and have a $200K maximum grant.

The I&I program provides an orderly approach to identifying qualified proposals to fund using the steps below:

- Solicitation development
- Proposal evaluation
- Program-relevancy review
- Energy-savings analysis
- Monitoring and tracking
- Commercialization assistance
- Evaluation

Solicitation Development

Generally, changes to the solicitation are minor; but some major changes in emphasis have occurred over the lifetime of the I&I Program. There is more emphasis on the commercialization strategy of the applicant, and each applicant is required to articulate that strategy. Another major change has been the increased documentation of energy-savings methodologies and the definition of the "commercially available unit of production." The applicants are now required to make comparisons to existing commercially available technologies.

Proposal Evaluation

The changes in the solicitation have been designed to make it easier for the reviewer to adequately and fairly judge the invention's energy savings, compared to the savings of existing and commercially available technologies. The technical coefficients (fuel use per year) are approved by the reviewers.

These relatively small grants ($40K-$200K) do not call for the same rigorous market analysis that would occur on much larger grants or continuing programs. However, all grants do undergo a thorough technical and market evaluation.

Program-Relevancy Review

As part of the lengthy selection process, the I&I Program requires the designated EERE program manager to review every proposal within the office's technical scope. This review enables the I&I DOE project manager to eliminate grant proposals that are outside the scope of EERE. It also familiarizes the EERE program managers with potential I&I grants that could potentially segue with their ongoing portfolios.

Energy-Savings Analysis

As I&I conducts a solicitation each year, and the selection of technologies are only bounded by EERE program scope, it is impossible to predict the FY05 program. As a result, the FY04 program is used to estimate the FY05 savings potential.

For the I&I Program, the PNNL GPRA Team analyzes the impact of each selected technology using a model developed for DOE-OIT (Technology Impact Projections Model, Energetics, Inc.) to be applied to industrial technologies considered in the GPRA process. The NEMS-PNNL model, used for most of the analysis in this report, does not have a detailed industrial sector. This generally precludes NEMS-PNNL from being used to model I&I technologies.

The DOE-OIT model only considers the market segment appropriate for a given I&I technology. However, fuel prices, electrical plant heat rates, and environmental emissions rates are taken from EIA forecasts and applied to all technologies. All proposals to I&I contain estimates of current technology performance, the expected performance of the proposed technology, and the suggested market segment. Markets can be defined in terms of annual sales or manufacturing capacity.

Performance estimates are reviewed with the inventor and adjusted for items such as heat rates and fuel mix that differ from the EIA base data. Performance coefficients are prepared for a "Technology Unit" in terms of fuel use per year of operation. For example, a technology unit for the ethanol industry is a production capability of 10,000,000 gallons per year. Multiplying the fuel coefficients by the number of units derives total annual fuel use.

The market segment size is defined in terms of a number of technical units. Initial segment size is based on data from sources such as EIA, trade associations, and DOE industry profiles. Most of the inventors have studied the markets for their technology and offer additional sources and insights. The sector growth rate is derived from similar sources. The inventor proposes a year when the technology would first enter the market, however, when questioned by PNNL, most inventors delay the date from the original proposal.

Maximum market-share limitations are placed on each technology. Factors that limit the share are technology issues, such as the technology will only work on motors more than a certain size; and market issues, such as the technology will be effective only in certain climates. Commercialization plans that use exclusive licensing can limit market share. In a case where two inventors are addressing the same market, the maximum market is cut in half. As I&I technologies either already have intellectual property protection or are in the process of establishing protection, the technology life cycle is set at 15 years. However, to simulate continued program funding at current rates, the life cycle is extended to 2030.

The DOE-OIT model offers four market penetration "s curves." Each is defined in terms of the number of years required to reach 50% of the maximum market share within the defined segment. The choice of "s curve" is based on the new technology performance advantage, the inventor's commercialization plan, the market segment characteristics, and experience of the I&I tracking program for the same segment or type of technology. An inventor that has a development partner who represents a major share of the market segment would be assigned an "s curve" implying a shorter time to reach a 50% of maximum share than an inventor with no partner. Technologies that require large capital investment are given slower "s curves." General instructions supplied to model users are included in **Appendix A**.

Annual estimates of "technology unit" sales and total units installed are made for each technology, based on the above inputs. Energy, economic, and environmental consequences are derived based on the installed unit forecast. The model results are discussed with each inventor and a signed agreement obtained. Generally, model results show fewer units sold than the inventors suggested in their proposals to I&I. A summary of the model results for each technology is part of the I&I Fact Sheets available on the I&I Web site.[q]

Calculations walk-through:

1) Annual market size is calculated from initial market size in "technical units," multiplied by market limitation fractions, and adjusted for market growth.
2) Annual market is multiplied by the market share from the selected "s curve" to derive annual sales.
3) Annual installed capacity is the total sales (to date) in technical units.
4) Energy savings are calculated by fuel type from the difference in performance coefficients between the new and current technology's technical units.
5) Other impacts are calculated from EIA prices and environmental coefficients multiplied by changes in annual fuel use.

Note: The market share is equal to the "s curve" fraction, multiplied by the market share limit fractions. Specific calculation inputs and associated estimates of program benefits are provided in **Appendix B.**

3.6.2 Target Market

Project Description. Descriptions of the activities on which outputs are based are included in **Appendix B**.

Market Description. Market segments are selected from public sources, as appropriate for each I&I technology. OIT's industry profiles are frequently used. Market limitations are introduced to better represent the true target of the technology. EIA forecasts of energy prices and electric power fuel mix are used for all cases.

Baseline market acceptance. The tracking of I&I technology acceptance provides an important input to the selection of the market penetration "s curve" and limitation of ultimate market share.

3.6.3 Methodology and Calculations

Inputs to base case. Because I&I cannot use NEMS-PNNL, each technology has its own base case. The same EIA fuel prices, electric plant fuel mix, and heat rate are used for all cases.

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[q] http://www.eere.energy.gov/inventions/

Technical characteristics. Technical coefficients of technology performance (i.e. fuel use per operating unit per year) are provided by the inventor and approved by the proposal reviewers.

Technical potential. The DOE-OIT model can only approximate 100% sales by removing market limitations and using the market penetration curve with five years to 50% of market.

Expected market uptake. The market penetration rate and limits consider many factors. The DOE-OIT model assumes that a technology with equal technical coefficients appears in the market at some time after the technology being evaluated is introduced. Depending on the strength of intellectual property protection, the time lag is usually 10 to 15 years.

Calculation results:

The FY04 grantees' energy savings are used to estimate FY05 results. FY04 had included 13 technologies (grants). Results for six technologies, representing about 85% of program savings, are shown in **Appendix B** to illustrate the I&I's energy-saving impacts. Calculations were made using the above-described OIT model. Sources are noted for market size and growth rates. Comments on the main factors considered in the "s curve" selection appear after the market-penetration percentages.

I&I Appendix A – Market Factor in Technology Impact Projections

The Technology Impact Projections model is used to estimate the potential security, economic, and environmental benefits resulting from research, development, and demonstration projects funded by the Inventions & Innovation Program (I&I). Benefit estimates are critical for evaluating projects and presenting the merits of both individual projects and the overall RD&D portfolio.

Market Inputs

To determine the potential impact of the new technology as it becomes adopted, it is necessary to estimate the total market for the technology, reduce that estimate to the likely actual market, and estimate when (and the rate at which) the new technology will penetrate the market.

Total Market

Total market: the number of units that perform the same task as the proposed technology. Only the domestic U.S. market should be included.

Number of Installed Units in U.S. Market
Please define that market as narrowly as possible: i.e. the smallest group of applications that covers all potential applications for which you may have some data. You may base your estimate on the energy use of the state-of-the-art technology and the energy-use data provided in this package. Other potential data sources include OIT's Energy and Environmental Profile for the relevant industry, EIA's MECS data, or industry sources.

Annual Market Growth Rate
This should be based on an EIA or industry growth projection for the relevant industry.

Market Share

Market share is a function of the potential accessible market share and the likely market share.

Potential Accessible Market Share
The accessible market: The market that the new technology could reasonably access given technical, cost, and other limitations of the technology. For example, certain technologies may be applicable only to a certain scale of plant, certain temperature-range processes, certain types of existing equipment or subsystems, or only certain segments of the industry.

Likely Market Share
In some instances, in addition to technical and cost factors, the technology may compete with other new technology approaches, or with other companies, for the market. Please estimate the likely market share. Use current market-share information, or base estimated market share on the basis of the number of competitors in the market, assuming they are

using different technologies not resulting from this project. This is different than the possibility of “copycats,” which should not be considered as competing. That is, if others adopt essentially the same, or slightly modified, technology due to this new technology, that adoption was triggered by the project being described and that project should be “credited” with causing that trend. This is potentially the case for techniques where the intellectual property cannot be, or is not, protected and becomes general knowledge throughout the industry.

Market Penetration

To understand how rapidly the potential impact of the technology will occur, the market penetration of the technology must be projected. This is based on two estimates, the technology development and commercialization timeline, and the market penetration curve.

Technology Development & Commercialization Timeline
The commercial introduction of a technology normally occurs after a significant demonstration or operating prototype and after an adequate test-and-evaluation period, along with allowances for the beginnings of production, dissemination of information, initial marketing and sales, or other “start-up” factors. To capture this lengthy process, please indicate the timeline for developing and introducing the technology into the market. This includes the years for when an initial prototype, refined prototype, and commercial prototype of the technology has or will be completed and the year when the technology will be commercially introduced. An initial prototype is the first prototype of the technology. A refined prototype represents changes to the initial prototype but not a commercially scaled-up version. A commercial prototype is commercial-scale version of the technology. Commercial introduction is when the first unit beyond the commercial prototype is operating. Prototype and commercial introduction years should be consistent with your technology-development program plans.

Market Penetration Curve (Technology Class)
New technologies normally penetrate a market following a familiar “s” curve, the lower end representing the above uncertainties overcome by “early adopters.” The curve tails off at the far future, where some may never adopt the new technology. The major portion of the “s” curve, where the new technology is penetrating the market and benefits are being reaped, is the most important. The rate at which technologies penetrate their markets varies significantly: Penetration of heavy industrial technologies generally takes place over decades, while simple process or control changes can penetrate much more rapidly. The actual penetration rate varies. due to many factors including economic, environmental, competitive position, productivity, regulatory, and others.

To assist in “s curve” selection, a large volume of actual penetration rates of past and present technologies were analyzed, normalized, and grouped into five classes, based on a number of characteristics and criteria. Those criteria have been distilled to the five choices in **Table A1.** Analysts and/or applicants can choose either a, b, c, d, or e as the rate class that best fits a given technology. Note that the characteristics (rows) are relatively independent, and a given technology will likely fit best in different classes for different characteristics. Selection of the most likely “rate class” at which the new technology may penetrate the market is based on best judgment and experience. This may be a "subjective average" of the characteristics, or it may be that one or two characteristics are believed to so dominate future adoption decisions that a particular class of penetration rate is justified. There also may be "windows of opportunity" where significant replacements of existing equipment may be expected to occur at some point for other reasons.

For additional assistance, **Table A2** shows actual technologies and the class of their historical penetration rates. Comparison of the new technology (by analogy or similarity) with these examples provides additional insight into selecting the appropriate penetration rate that might be expected for the new technology.

Table A1. Selecting the Market-Penetration Rate Class

Technology/project						**Score (a,b,c,d,e)**
Characteristic	**a**	**b**	**c**	**d**	**e**	
Time to saturation	5 yrs	10 yrs	20 yrs	40 yrs	>40 yrs	na
Technology factors						
Payback discretionary	<<1 yrs	<1 yr	1-3 yrs	3-5 yrs	>5 yrs	
Payback non-discretionary	<<1 yr	<1 yr	1-2 yrs	2-3 yrs	>3 yrs	
Equipment life	<5 yrs	5-15 yrs	15-25 yrs	25-40 yrs	>40 yrs	
Equipment replacement	none	minor	unit operation	plant section	entire plant	
Impact on product quality	$$	$$	$$	$	0/-	
Impact on plant productivity	$$	$$	$$	$	0/-	
Technology experience	new to U.S. only	new to U.S. only	new to industry	new	new	
Industry factors						
Growth (%per annum)	>5%	>5%	2-5%	1-2%	<1%	
Attitude to risk	open	open	Cautious	conservative	averse	
External factors	forcing	forcing	Driving	none	none	na
Gov't regulation						
Other						

Table A2. Penetration Rate of Technologies.

Class	A	B	C	D	E
Aluminum		Treatment of used cathode liners	Strip casting, VOC incinerators		
Chemicals	New series of dehydrogenation catalyst (incremental change)	CFCs -> HCFCs, incrementally improved catalysts, membrane-baed chlor-alkali	Polypropylene catalysts, solvent to water-based paints, PPE-based AN	Synthetic rubber & fibers	
Forest Products			Impulse drying, de-inking of waste newspaper	Kraft pulping, continuous paper machines	
Glass		Lubbers glass blowing, Pilkington float glass	Particulate control, regenerative melters, oxygenase in glass furnaces		
Metals Casting	New shop floor practice				
Petroleum	New series HDS catalysts	Alkylation gasoline	Thermal cracking, catalytic cracking	Residue gasification, flexicoking	

I&I Appendix B – I&I Energy Savings Results

I&I Technology			**Pulse paper drying**			
Technology Description - Virtually all paper manufacturing equipment worldwide is limited by the evaporative drying stage. The most common air-drying process improves efficiency of this process by 59% and speeds overall paper production 21%.						
Market segment is the paper manufacturing industry - technology unit is a plant producing 44,000 tons/yr						
Current technology units in operation - 2002			290	Source - DOE - OIT technology profile		
Sector annual growth rate			1%	Source - DOE - OIT technology profile		
New technology Introduction year			2006			
Savings per new install unit			235 Billion Btu (Natural gas)/year			
Year	2008	2010	2015	2020	2025	2030
Units in service	5	13	78	178	215	227
Annual unit sales	2	4	20	15	4	0
Primary energy savings	1.2	2.9	18.2	41.6	50.3	53.1
(trillion Btu/year)						
Market Penetration	2%	4%	24%	51%	59%	60%
Note: Industry is aware of this technology, but waits for the early adapter. Most plants in the industry are owned by a few companies, success will move quickly although the units are expensive. (10yr curve)						

I&I Technology	**High Speed/ Low Effluent process for Wet and Dry Mill Corn to Ethanol**					
Technology Description - A high speed/low effluent fermentation process based on the BPSC-15 yeast that has the property of forming stable high strength 'pellets'. Very high cell densities are easily attained with this yeast, which leads to quick and complete fermentations Energy use reduced by 42% and requires fewer fermenters for the same production rate.						
Market segment is the ethanol manufacturing industry - technology unit is a plant producing 10,000,000 gal/yr						
Current technology units in operation - 2001			177	Source - EIA's Annual Energy Outlook 2001		
Sector annual growth rate			10%	Source - Energy Bill (5 Billion Gal by 2012)		
New technology Introduction year			2006			
Savings per new install unit			228,000 Million Btu (Coal)/year			
Year	2008	2010	2015	2020	2025	2030
Units in service	6	32	171	284	458	728
Units starting operation	4	17	22	26	42	58
Primary energy savings	1.4	7.3	39.1	64.8	104	166
(trillion Btu/year)						
Market Penetration	2%	8%	25%	26%	26%	26%
Note: Technology can be retrofitted or used with new plants. Retrofit costs are about 5% of original cost, but new plant would see a cost reduction (few fermenting units) in addition to energy savings. (5 yr curve)						

I&I Technology	**Electrochromic Windows - Advanced Processing Technology**					
The project is focused on developing advanced fabrication capabilities for energy-saving electrochromic (EC) smart windows. SAGE EC devices consist of an alt-ceramic stack of thin film coatings on a glass substrate. The window tint can be changed electrically by the application of low voltage DC power. SAGE has developed the basic materials and device technologies and moved operations from laboratory to pilot line.						
Market segment is residential and commercial windows - technology unit is 1 million Sq-meters of glazing						
Current technology units in operation - 2001			3000	Source - Implied from annual sales		
Sector annual growth rate			3%	Source - "Smart Windows" an SRI study		
New technology Introduction year			2005			
Savings per new install unit			304 billion Btu(gas, oil and Elect) /year			
Year	2005	2010	2015	2020	2025	2030
Units in service	11	106	617	1287	1638	1896
Units sold	11	37	147	103	58	34
Primary energy savings	3.6	32.4	182.5	375.3	477.5	552.8
(trillion Btu/year)						
Market Penetration	0%	3%	14%	25%	28%	28%
Note: Early years sales based on SRI markets study with later years keyed to LBNL saturation estimates referenced by the inventor.(10yr curve)						

I&I Technology	**Multi-rotor Micro Particle Generator**					
This mechanical generator incorporates a novel approach to continuous emulsification processing of any type of fine particle homogeneous suspensions. Through exceptionally efficient and effective particle size reduction or, in the case of organic materials, cell disruption, thus greater starch exposure. This process eliminates the current Jet Cooking process used to reach the "liquefaction stage" in the production of corn ethanol, saving up to 46% of the related energy costs.						
Market segment is the ethanol manufacturing industry - technology unit is a plant producing 10,000,000 gal/yr						
Current technology units in operation - 2001			177	Source - EIA's Annual Energy Outlook 2001		
Sector annual growth rate			10%	Source - Energy Bill (5 Billion Gal by 2012)		
New technology Introduction year			2004			
Savings per new install unit			37,400 Million Btu (Coal)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	2	77	176	284	458	728
Units sold	1	28	17	26	42	58
Primary energy savings	0.1	2.9	6.7	10.9	17.6	28.0
(trillion Btu/year)						
Market Penetration	1%	19%	26%	26%	26%	26%
Note: Basic technology exists, but has not been applied to corn. After testing and any necessary modifications units can be sold to new or retrofitted to existing plants. (5yr curve)						

I&I Technology	**High Efficiency Variable Dehumidification for Air Conditioners**					
The project goal is to produce a production prototype that will lead industry to a highly marketable improvement in energy efficiency, dehumidification, and maintenance of like-new performance for unitary air-conditioning and dehumidification.						
Market segment is Commercial and Residential AC - technology unit delivers 20,000 ton-hr/year						
Current technology units sales - 2002			5.42 million	Source - ADL report for OBT		
Sector annual growth rate			2%	Source - ADL report for OBT		
New technology Introduction year			2006			
Savings per new install unit			142 Million Btu (Electricity)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	0	108,198	700,628	1,683,669	2,138,463	2,371,813
Units sold	0	38,179	186,332	156,923	63,456	20,493
Primary energy savings	0.0	11.6	68.9	158.1	201	223
(trillion Btu/year)						
Market penetration		2%	10%	22%	25%	25%
Note: Technology requires major AC unit design changes, but with result little or no cost increase. Market is limited to regions with high humidity- Southeast and portions of South and Midwest. (10yr curve)						

I&I Technology	**Medium Voltage Energy Saving Motor Controller**					
Concept for a medium voltage electric motor controller that cost-effectively reduces energy consumption by up to 35% for underloaded medium voltage (2300-4600V) electric motors. While large electric motors comprise only 0.3% of the number of motors used in US manufacturing, they consume 19% of the total motor energy. When a motor is loaded less than 40% of its full load, its efficiency declines quickly.						
Market segment is Electric motors - technology unit a 1000 HP motor running at part load						
Current technology units sales - 1997			89,500	Source - DOE Motor Challenge data		
Sector annual growth rate			3%	Source - DOE Motor Challenge data		
New technology Introduction year			2006			
Savings per new install unit			4,466 Million Btu (Electricity)/year			
Year	2005	2010	2015	2020	2025	2030
Units in service	0	1123	3747	11363	26365	46524
Units sold	0	245	787	2149	3775	3825
Primary energy savings	0	5.0	15.3	44.4	103.0	181.7
(trillion Btu/year)						
Market Penetration	0%	1%	2%	6%	13%	20%

Note: Market is limited to motors over 200HP that operate at less the 40% of full load. The inventor already supplies controllers for smaller motors. Research will develop capability for larger motors. The inventor company knows the industry and provided market forecasts based on his own experience.(20yr curve)						