CHAPTER 4

MIDTERM BENEFITS ANALYSIS OF EERE'S PROGRAMS

Introduction

The results of the **Step 2** program and market analyses are incorporated into NEMS-GPRA05 in the Program and Portfolio Cases to estimate the midterm (to 2025) benefits for each program and for EERE's overall portfolio. In some cases, NEMS-GPRA05 can directly utilize program performance goals (outputs). In other cases, analysts need to make adjustments to the program analyses when incorporating them in NEMS-GPRA05. This chapter describes the NEMS-GPRA05 analyses for each program. The appendices provide additional information on the inputs provided by each program.

Table 4.1 shows a breakdown by program of the two types of analytical tool employed in its benefits analyses—specialized "off-line" tools and NEMS-GPRA05. A description of EIA's NEMS model is provided in **Box 4.1** at the end of this chapter. Descriptions of the off-line tools are provided in the related program appendix.

Table 4.1. Program Benefits Modeling by Primary Type of Model Used and Activity Area

Program	Activity Area	Off-Line Tool	NEMS-GPRA05
Biomass	Bio-based Products	✓	
	Cellulosic Ethanol	✓	✓
Building Technologies	Technology R&D	✓	✓
	Regulatory Actions	✓	✓
	Market Enhancement	✓	
DER	DER		✓
FEMP	FEMP	✓	
Geothermal	Geothermal		✓
Hydrogen, Fuel Cells, and Infrastructure Technologies	Fuel Cells		✓
	Production	✓	
Industrial Technologies	R&D	✓	
	Deployment	✓	
Solar Energy Technologies	Solar Water Heaters		✓
	Photovoltaics	✓	✓
Vehicle Technologies	Light Vehicle Hybrid and Diesel		✓
	Heavy Vehicles	✓	
Weatherization and Intergovernmental	Weatherization	✓	
	Domestic Intergovernmental	✓	
Wind and Hydropower Technologies	Wind		✓
	Hydropower	✓	

Required off-line analysis can range from simple verification of program goals to an initial calculation of energy savings, depending on the treatment of the target market in NEMS-GPRA05 and the nature of the program. Analysts use specialized off-line tools to develop the inputs to NEMS-GPRA05 for each program case. The activity areas listed are groupings of activities within each program that share either technology or market features. They do not represent actual program-management categories.

Biomass Program

The goal of the Biomass Program is the development of biomass refineries, which produce a range of products including ethanol and biochemical feedstocks. This refinery approach reduces the cost of these biomass products compared to the earlier approach of individually producing each product. Unfortunately, it is currently not possible to directly model a biorefinery. Instead, analysts model individual biorefinery products (bio-based products and cellulosic ethanol) for the benefits analysis. This most likely results in an underestimation of the size of future markets and resulting benefits.

Bio-based products: The bio-based products activities seek to develop biomass-based chemical products through innovative biomass-conversion processes. The use of biomass would displace the use of petroleum and natural gas as chemical feedstocks. Because of the multitude of products and the complexity of the chemicals industry, NEMS-GPRA05 does not have sufficient detail within its representation of this industry to explicitly model bio-based products. Given the lack of a bio-based products sector in the model, analysts assessed energy savings off-line. The energy savings by fuel type (the largest share was petroleum feedstocks) were implemented in the integrated model, by subtracting the estimates from industrial energy consumption otherwise projected by NEMS-GPRA05. Analysts then used the model to compute the other benefits of primary energy savings, carbon emission reductions, and energy-expenditure savings.

Cellulosic ethanol: Cellulosic ethanol research is aimed at reducing the cost of producing ethanol from cellulosic biomass.[1] Estimates of future cellulosic ethanol production costs in the *AEO2003* and the Baseline Case are comparable. The biomass-to-ethanol conversion efficiencies for both the Baseline and Program Cases reflect more updated information than the *AEO2003* assumptions. In the *AEO2003*, EIA assumed that the growth in projected production was constrained by a number of factors in addition to ethanol production costs. In the Baseline Case, EERE was more conservative in terms of constraining the growth in ethanol production in the absence of EERE programs. EERE’s biofuels analytic model, ELSAS, was used to estimate ethanol growth, with the enzyme-based technology for converting the cellulose and hemi-cellulose from the fiber contained in corn kernels will be available sooner than the related (but more complex) enzyme-based technology for converting agricultural residues to ethanol. NEMS-GPRA05 then adjusted the overall level of ethanol purchased by considering the price impacts of competing sources of demand for biomass (*e.g.*, for electricity production). Petroleum and fossil energy savings occur when the cellulosic ethanol displaces gasoline through enhanced blending. In the FY 2005 EERE benefits estimates, a large portion of the cellulosic ethanol displaces corn ethanol, which leads to fossil energy and carbon emission savings based on recent EERE life-cycle analysis. Analysts performed the adjustment for fossil energy and carbon reduction outside of NEMS-GPRA05, using results from EERE’s Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model.

[1] Cellulose and hemi-cellulose that can be converted to ethanol (and other chemicals, materials, and biofuels) are found in biomass such as agricultural residues (corn stover, wheat, and rice straw), mill residues, organic constituents of municipal solid wastes, wood wastes from forests, future grass, and tree crops dedicated to bio-energy production.

Table 4.2. FY05 Benefits Estimates for Biomass Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.04	0.06	0.09	0.15
Cellulosic Ethanol Production (billion gallons/yr)	0.11	0.28	0.62	1.46
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	0.0	0.0	1.2	1.7
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.5	0.8	1.4	2.7
Security				
Oil Savings (mbpd)	0.01	0.02	0.02	0.03
Natural Gas Savings (quadrillion Btu/yr)	0.01	0.02	0.02	0.04
Avoided Additions to Central Conventional Power (gigawatts)	ns	ns	ns	ns

Building Technologies Program

The activities of the Building Technologies Program can be classified into three general types: technology R&D, regulatory actions, and (to a far lesser extent) market enhancement.[2] The modeling approach and applicable end uses for the activities that comprise the Building Technologies Program are displayed in **Table 4.3**. Analysts model the technology R&D activities by modifying costs and efficiencies of the equipment and shell technology slates. Market-enhancement activities and some regulatory activities (such as buildings codes) are modeled using penetration rates and energy-savings estimates. A few R&D activities such as residential incandescent can light fixtures were not modeled, because they represented a small segment of the market and are not explicitly represented within NEMS-GPRA05.

Technology R&D: The technology R&D activities seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The forecast benefits for these are measured by modifying the technology slates from those that are available in the Baseline Case to reflect the program goals. Building technologies in NEMS-GPRA05 are represented by end use. For most end uses, there are conversion technologies (*e.g.*, furnaces and water heaters) that use different fuels and that have several different levels of energy efficiency. The Baseline Case incorporates EIA's estimation of future technology improvement that is then modified in the Program Case.

Residential shell technologies, such as windows or insulation, are represented by several packages of technologies with different levels of improvements. Each package is characterized by a capital cost and heating and cooling load reductions. The commercial-sector shell measures are represented by window and insulation technologies that can be selected individually. EIA developed the residential methodology for the *AEO2001*, while OnLocation developed the commercial methodology for EERE.

[2] With the reorganization of EERE, the overwhelming majority of the market-enhancement activities are part of the Weatherization and Intergovernmental Program.

Table 4.3. Modeling Approach for Building Technologies Program Activities

Building Technology Project List	Sector		End-Use					Modeling Approach		
	Resd	Comm	Heat	Cool	Water Heating	Lighting	Other	Energy Savings and Penetration Rates	Equipment Technology Costs and Efficiencies	Shell Technology Costs and Efficiencies
Residential Buildings Team										
Residential Energy Codes	✓		✓	✓				✓		
Technology Research and Development	✓		✓	✓	✓	✓	✓			✓
Commercial Buildings Team										
Commercial Energy Codes		✓	✓	✓		✓		✓		
Technology Research and Development		✓	✓	✓				✓		
Building Equipment Team										
Equipment Standards and Analysis										
EPAct Standards		✓	✓	✓					✓	
Emerging Technologies Team										
Analysis Tools and Design Strategies		✓	✓	✓				✓		
Appliances and Emerging Techn. R&D										
Heat Pump Water Heater	✓				✓				✓	
Roof top AC		✓		✓					✓	
Incandescent Can Light Fixtures	✓					✓				
R-Lamp	✓					✓				
Envelope Research and Development										
Electrochromic Windows		✓	✓	✓		✓				✓
Superwindows/Low-e Windows	✓		✓	✓				✓		✓
Lighting Research and Development										
Lighting Controls		✓				✓		✓		
Next Generation Lighting	✓	✓				✓			✓	
Space Conditioning and Refrigeration R&D										
HVAC Distribution System		✓	✓	✓				✓		
Advanced Electric HPWH	✓								✓	
Commercial Refrigeration										
Refrigerant Meter		✓	✓	✓						✓

The residential and commercial sectors are each represented by several building types within nine Census divisions. NEMS-GPRA05 computes end-use technology choice for each of these building types and geographic regions, based on the relative economics and estimations of consumer behavior for the technologies. The latter is important to replicate current technology market shares.

Improved EERE technologies that have no incremental costs above the baseline technologies must be treated differently. If they were introduced into the modeling framework as technologies with zero incremental costs, there would be immediate adoption and unrealistic market shares. Thus, for these activities, program penetration estimates developed off-line are used to compute a target savings.[3] These savings were achieved in NEMS-GPRA05 by lowering the consumer

[3] The target savings, however, are first reduced by 5 percent to 50 percent, as are other program estimates that cannot be modeled within NEMS-GPRA05. These percentages were based on the extent of overlap with other program activities. The revision is based on the expert judgment of the benefits analysis team.

hurdle rates for the appropriate end uses or by modifying the autonomous shell efficiency indices.

Regulatory activities: Regulatory activities include setting new appliance standards, based on the legislatively mandated schedule and encouraging state adoption of more stringent building codes.[4] Representing appliance standards is straightforward. In the year that the program expects the new standard to be implemented, all technologies that are less efficient than the standard are removed from the market and unavailable for consumer choice. The resulting energy savings depend on the difference in the level of efficiency of the standard compared to the technology that had been selected in the Baseline Case.

Market enhancement: Building-code development is primarily a regulatory activity, although it also involves outreach to encourage the various states to adopt new and stricter standards. Analysts make a spreadsheet computation of average savings using off-line estimates for the fraction of buildings within areas that adopt more stringent codes, as well as the heating, cooling, and lighting load reductions associated with the new levels of codes. The building shell packages are modified to produce the appropriate savings.

The Building Technologies Program results in energy savings primarily in four end-use categories: space heating, space cooling, water heating, and lighting. **Table 4.4** demonstrates the level of savings from each category. In 2025, lighting energy-use reduction is the largest share of the total savings in both the residential and commercial sectors. Space heating and cooling also show significant savings. Water-heating savings occur only in the residential sector.[5]

Table 4.4. Building Technologies Program Energy Savings by End Use

Energy Reduction	Residential				Commercial			
Percentage	2010	2015	2020	2025	2010	2015	2020	2025
Space Heating	1%	3%	5%	6%	2%	4%	5%	7%
Space Cooling	0%	1%	2%	4%	2%	5%	7%	9%
Water Heating	3%	5%	5%	6%	0%	0%	-1%	-1%
Lighting	0%	0%	1%	16%	1%	2%	8%	16%
Other	0%	0%	0%	0%	0%	0%	0%	0%

Analysts estimate the Building Technologies Program benefits (**Table 4.5**) within the integrated NEMS-GPRA05, so that the electricity-related primary energy savings are directly computed. In addition, the estimates include any feedbacks in the buildings or other sectors resulting from changes in energy prices that result from the reduced energy consumption.

[4] The outreach/deployment aspects of the codes process occur with funding provided by the Weatherization and Intergovernmental Program.

[5] The very small increase in commercial water-heating consumption (shown as a negative savings in Table 4.4) stems from a response to lower energy prices. The lower energy prices result from reduced energy consumption in buildings and other sectors.

Table 4.5. FY05 Benefits Estimates for Building Technologies Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.33	0.66	1.12	2.03
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	4	10	16	27
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	6	13	22	43
Security				
Oil Savings (mbpd)	0.02	0.03	0.04	0.08
Natural Gas Savings (quadrillion Btu/yr)	0.15	0.33	0.54	0.78
Avoided Additions to Central Conventional Power (gigawatts)	3	8	16	26
Total Electricity Capacity Avoided (gigawatts)	5	10	21	36

Distributed Energy Resources Program

The Distributed Energy Resources (DER) Program encompasses many technologies and markets. The benefits were estimated by focusing on several segments of the distributed energy market: gas-fired combined heat and power (CHP) systems in commercial building and industrial applications, and non-CHP grid support applications. Distributed energy resource applications that are motivated by the need for electric reliability primarily will be systems that produce only electricity and are used in backup mode. In the program analysis, these are represented as grid-support DER for their similar technology characteristics, although the model treats them as though they are purchased by electric-power producers rather than electricity-consuming businesses. The value of these systems is difficult to capture in the GPRA benefits metrics. They do not provide significant energy or emissions savings, because they run for only a few hours per year and generally have similar or lower efficiencies than larger central-station peaking facilities. They do have the potential to contribute significantly to new electric power-generating capacity. The benefit estimates do not account for increased reliability and local Clean Air Act impacts on demand.

Combined heat and power systems produce both useful thermal heat and electricity. Their economics depend on the amount of thermal heat needed at the site, the electricity usage at the site, the price of the input fuel, and the value of the electricity. If the end-use customer is making the investment, the electricity value will depend on the customer-avoided purchases at the electricity retail price, and possibly the amount of excess electricity sold off-site at prevailing wholesale electricity prices. Using the average electricity price is a simplification that may overlook the requirement to continue paying some type of flat distribution charge, even though less electricity is purchased from the utility. If a vertically integrated electric utility is making the investment, the value is from avoided generation, and transmission and distribution (T&D) costs. The distributed systems would be placed strategically in the grid to avoid T&D expansion costs.

The DER Program facilitates the development of the DER market by improving the technology characteristics (lowering costs, improving efficiency, and reducing environmental emissions) and by removing barriers to adoption and consumer acceptance. Thus, the benefits are estimated based on the impact of improved technology and greater market penetration.

Baseline adjustments: The *AEO2003* Reference Case includes significant DER technological advancement. The Baseline Case included a modified set of technology characteristics that represented the absence of continued EERE programs. These modifications were made in all three areas in NEMS where distributed technologies are represented: commercial building combined heat and power (CHP), industrial CHP, and utility grid support. The technology assumptions for commercial gas-fired chillers also were modified, and these chillers were assumed to be applicable to all building types; unlike in the *AEO2003,* where they can be used only in the larger building sizes.

The adoption rates of distributed technologies in commercial buildings were modified to reflect market data gathered by EERE on consumer adoption of energy efficiency projects as a function of payback time (**Figure 4.1**).[6] The NEMS-GPRA05 framework uses a cash-flow model to evaluate the DER technologies—CHP and photovoltaic (PV) systems—within the building sectors. For commercial buildings, debt and interest payments are computed over a loan period of 20 years along with associated taxes and tax benefits and assuming a 20 percent down payment. Annual fixed maintenance costs also are included. For the gas-fired CHP technologies, NEMS-GPRA05 computes fuel costs based on the delivered cost of natural gas and the technology efficiency. The value of the useful waste heat produced is netted against the fuel cost, based on the delivered natural gas price, the thermal efficiency of the CHP system, and the internal thermal load. The value of the electricity produced is then subtracted from these costs to determine the cash flow. The value of electricity is equal to the larger of the electricity produced and the internal electricity demand, multiplied by the delivered electricity price. Any electricity produced in excess of internal needs is assumed to be sold to the grid at the wholesale rate. The number of years until positive cash flow is reached determines the market share in new buildings. The market share for existing buildings is assumed to be a fraction of the share for new.

Under both the EIA and program assumptions, market share in new buildings decreases sharply as the number of years required to achieve positive cash flows increases. This reflects the high rates of return generally expected for energy-related projects by commercial-building owners. These shares apply to the fraction of commercial buildings assumed to be eligible for an installation of distributed CHP. The *AEO2003* eligibility fraction assumption of 30 percent was increased to 50 percent. These adoption rate changes were made in the Baseline Case as well as the Program Case.

Technology improvements: The program provided characteristics for distributed energy systems that reflect the program's research goals. These included commercial CHP systems (gas engines, gas turbines, gas micro turbines), commercial gas-fired chillers, industrial CHP (five systems sizes for gas-fired engines and turbines), and grid-support DER (base and peaking).

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[6] ***Market Trends in the U.S. ESCO Industry: Results from the NAESCO Database Project***. Goldman, C., J. Osborn and N. Hopper, LBNL, and T. Singer, NAESCO, May 2002, LBNL-49601.

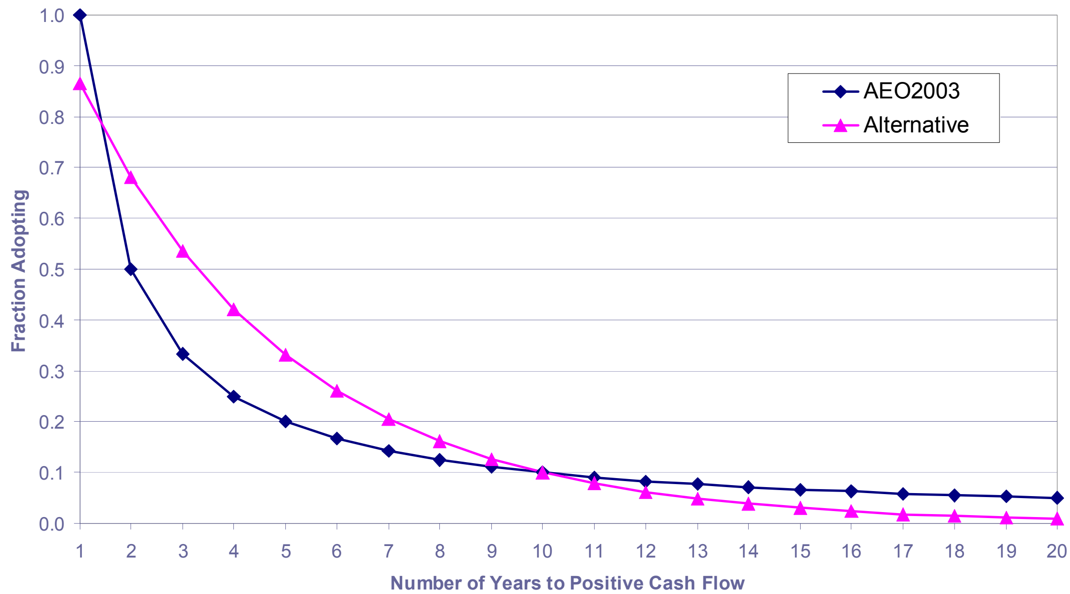


Figure 4.1. Commercial-Sector DG Adoption Rates

Market enhancement: The DER Program's impact on consumer-adoption rates was represented primarily for smaller distributed energy in commercial buildings. As described previously, the DER market share for the existing building stock in NEMS-GPRA05 is tied to the market share computed for new buildings. The baseline (and *AEO2003*) assumption is that the fraction of existing buildings that will adopt DER in a given year is one-fiftieth of the share for new buildings. For the Program Case, this was accelerated to one-tenth each year. Note that the adoption rate for the existing stock of buildings is considerably smaller than the market share for new buildings, reflecting that the entire existing stock will not make investments in distributed technologies as quickly as the increment that is built each year. Although the DER program does not impact PV technology performance, the rate of adoption of Baseline Case PV accelerates. This is due to the market-enhancement activities, as represented by the increased adoption rates in existing buildings. This share would likely grow if modeled in conjunction with the Solar Energy Technologies Program PV technology improvements.

The incremental DER capacity that results from this representation of the DER Program activities is shown in **Table 4.6**, along with the projected total quantities. Of the 64 GW of incremental capacity by 2025, more than 75 percent of the increase is expected from commercial-building applications, roughly 5 percent from generally larger industrial applications, and the remaining from grid-support systems.

In the Baseline Case, by 2025, the commercial sector is projected to satisfy roughly 3 percent of its total electricity demand with distributed generation, and the industrial sector 16 percent. With the DER Program, the share increases to 18 percent in the commercial sector and 17 percent in the industrial sector.

Table 4.6. Distributed Energy Resources Capacity (GW)

	2005	2010	2015	2020	2025
AEO Base					
Buildings	1.2	1.5	1.7	2.4	3.7
Industry*	29.9	33.1	35.9	39.2	43.8
Electric Industry	0.3	1.7	5.1	10.1	15.9
Baseline Case					
Buildings	1.8	1.9	2.3	5.5	15.1
Industry*	29.8	32.9	35.5	38.7	42.9
Electric Industry	1.8	8.6	18.6	32.9	55.6
Benefits Case					
Buildings	2.3	6.9	17.1	33.8	64.0
Industry*	29.9	33.1	35.9	39.7	46.1
Electric Industry	2.5	17.4	37.9	51.9	67.0
Incremental Capacity					
Buildings	0.5	5.1	14.8	28.3	48.9
Industry*	0.1	0.2	0.4	1.0	3.2
Electric Industry	0.8	8.8	19.3	19.0	11.5
Total	1.4	14.1	34.5	48.3	63.6

* Excludes nontraditional, large qualifying facility cogenerators.

The DER Program benefits (**Table 4.7**) are projected within the integrated modeling framework, so that the impact of the program will be reflected in the rest of the energy system. As a result of increased investments in DER, electricity purchases from the commercial and industrial sectors are reduced, and additional electricity is sold wholesale to the grid.

Table 4.7. FY05 Benefits Estimates for DER* (NEMS-GPRA05)

Benefits	**2010**	**2015**	**2020**	**2025**
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.03	0.08	0.23	0.38
Generation (gigawatt-hours/yr)	28	102	194	315
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	2	3	7	11
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	1	6	10	15
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	-0.06	-0.30	-0.35	-0.50
Avoided Additions to Central Conventional Power (gigawatts)	11	38	55	80
Program-Specific Electric Capacity Additions (gigawatts)	14	35	48	64

* Includes increased market penetration for stationary fuel cells.

The central electricity-generation industry responds by reducing production from the most expensive plants operating in each region, and over time by building fewer central-station plants in the face of lower demand. Retirements are relatively unaffected, with only 6 GW of additional capacity retired by 2025 in the Program Case. Roughly 80 GW of central-station investments are avoided by the additional DER. In the Baseline Case, about 70 percent of new central-station capacity additions from 2005 to 2025 are projected to be natural gas fired, and about 80 percent of the avoided central-station investments are natural gas-fired turbines and combined-cycle plants. In 2025, roughly 65 percent of the avoided central generation is gas fired. In total, distributed generation makes up roughly 24 percent of new capacity additions from 2005 to 2025 in the Baseline Case. This share increases to 45 percent in the Program Case.

The energy- and carbon emission-reduction benefits that stem from distributed generation are computed as the decrease in traditional central-station nonrenewable energy consumption and associated carbon emissions, net of the energy and emissions from the DER. The central-station generation reductions are from a mix of existing plants and avoided new plants. Over time, the facilities that are used in the Baseline Case become more efficient as the gas combined-cycle and combustion turbine technologies continue to improve. As a result, the energy and emission savings from the central grid decline per kilowatt-hour.

Federal Energy Management Program

The Federal Energy Management Program (FEMP) is an implementation program to increase the energy efficiency of Federal Government buildings, which account for about 5 percent of U.S. commercial-building energy consumption. FEMP activities support the installation of a variety of existing technologies, rather than focusing on the development of specific technologies, as do many other EERE programs. Because it encompasses a broad technological scope—while, at the same time, targeting a specific market segment—FEMP is difficult to model in an integrated framework such as NEMS-GPRA05. However, there is also less uncertainty associated with achieved energy savings because the program tracks changes in Federal energy consumption.

Delivered energy savings (estimated off-line) are used as inputs for the integrated modeling. These projected savings are subtracted from the Baseline Case for commercial-building energy consumption. Analysts use the model to compute the other benefits metrics of primary energy savings, carbon emission reductions, and energy expenditure savings (**Table 4.8**).

Table 4.8. FY05 Benefits Estimates for FEMP (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Non-Renewable Energy Savings (quadrillion Btu/yr)	0.03	0.04	0.05	0.07
Economic				
Energy Expenditure Savings (billion 2001 dollars/yr)	0.2	0.3	0.5	0.6
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.5	0.8	1.1	1.5
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.02	0.02	0.02	0.02
Avoided Additions to Central Conventional Power (gigawatts)	0	0	1	1

Geothermal Technologies Program

The primary goal of the Geothermal Technologies Program is to reduce the cost of geothermal-generation technologies, including both conventional and enhanced geothermal systems (EGS). Measuring the benefits involves projecting the market share for these technologies, based on their economic and environmental characteristics.

The NEMS-GPRA05 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Geothermal capacity is treated in a unique manner, due to the specific geographic nature of the resources. The model characterizes 51 individual sites of known hydrothermal geothermal resources, each with a set of capital and operating and maintenance (O&M) costs. For the Program Case, an additional set of EGS sites were added to this slate.

The Geothermal Program was represented by reducing the capital and O&M costs for all hydrothermal geothermal sites, so that the average of the three lowest-cost sites matched the program cost goals, as reflected in the EERE/EPRI *Renewable Energy Technology Characterizations* report.[7] Separate program technology goals were provided for the added EGS sites. In addition, the program was assumed to reduce the risk associated with new geothermal development, and the Baseline Case limit on the size of annual developments per geothermal site was increased from 25 MW or 50 MW (depending on year) to 100 MW per year.

In addition to competing on an economic basis with other electricity-generation technologies, geothermal capacity may be constructed for its environmental benefit. Princeton Energy Resources International (PERI), using their Green Power Market Model, provided an estimate of geothermal capacity additions in response to the expanding green power markets in many places throughout the country. The projections for green power geothermal installations were incorporated into NEMS-GPRA05 as planned capacity additions.

Table 4.9 shows the resulting additional geothermal capacity and generation, by region and for capacity by technology type. The greatest incremental capacity is in California (CAL) and the Northwest (NWP), with less in the Rocky Mountain area (RA).

The primary energy, oil, and carbon emissions savings stem from geothermal power displacing fossil-fueled generation sources. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. **Table 4.10** shows the overall Geothermal Technologies Program benefits.

[7] EERE/EPRI (1997). *Renewable Energy Technology Characterizations*. EPRI-TR-109496.

Table 4.9. Geothermal Capacity and Generation

	2010	2015	2020	2025
GPRA Base Capacity (GW)				
NWP	1.0	1.5	2.2	2.6
RA	0.4	0.4	0.4	0.5
CAL	2.6	2.7	3.0	3.2
Total	3.9	4.6	5.7	6.3
Conventional	3.9	4.6	5.7	6.3
EGS	0.0	0.0	0.0	0.0
Program Case Capacity (GW)				
NWP	2.6	3.4	3.8	4.6
RA	0.4	0.7	0.8	1.3
CAL	3.5	4.0	5.3	6.3
Total	6.5	8.2	10.0	12.2
Conventional	6.5	8.2	8.7	8.8
EGS	0.0	0.0	1.2	3.4
Total	6.5	8.2	10.0	12.2
Incremental Capacity (GW)				
NWP	1.6	1.9	1.6	2.0
RA	0.1	0.3	0.4	0.8
CAL	0.9	1.4	2.3	3.0
Total	2.6	3.6	4.3	5.8
Conventional	2.6	3.6	3.0	2.4
EGS	0.0	0.0	1.2	3.4
Total	2.6	3.6	4.2	5.8
Incremental Generation (BkWh)				
NWP	12	16	13	16
RA	1	2	3	6
CAL	7	11	18	24
Total	20	29	35	46

Table 4.10. FY05 Benefits Estimates for Geothermal Technologies Program (NEMS-GPRA05)

Benefits	**2010**	**2015**	**2020**	**2025**
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.15	0.17	0.23	0.35
Generation (gigawatt-hours/yr)	20	29	35	46
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	0.6	1.6	1.8	1.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	2.7	2.3	4.1	6.7
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.08	0.18	0.16	0.20
Avoided Additions to Central Conventional Power (gigawatts)	2	2	4	5
Program-Specific Electric Capacity Additions (gigawatts)	3	4	4	6

Hydrogen, Fuel Cells, and Infrastructure Technologies Program

The Hydrogen, Fuel Cells, and Infrastructure Technologies Program is targeted toward the introduction of fuel cells for both stationary and vehicular applications, as well as the production and delivery of hydrogen at a reasonable price. NEMS-GPRA05 does not have a representation of hydrogen supply options. Therefore, a simple assumption was used that all hydrogen through 2025 would be derived from natural gas. The hydrogen conversion process was assumed to be 75 percent efficient and yield a hydrogen price of $1.50 per gallon of gasoline equivalent (excluding taxes) when the natural gas price is $4 per MMBtu.

The stationary fuel cell research is focused on distributed proton-exchange membrane (PEM) fuel cells. The program goals for their capital costs and efficiencies were taken from the multiyear program plan (MYPP). The MYPP provides goals through 2010, and no further improvements were assumed. This conservative assumption most likely understates the benefits of these fuel cells.

The fuel cell vehicles were modeled along with the Vehicle Technologies Program. The success of fuel cell vehicles is predicated on some of the vehicular improvements being developed under the Vehicle Technologies Program, so the fuel cell vehicles could not be treated in isolation. Analysts modified the gasoline and hydrogen fuel cell vehicle costs and efficiencies to reflect the program goals (see the Vehicle Technologies Program description for more detail about the modeling of vehicle choice). In addition, hydrogen availability for vehicle refueling was assumed to be 10 percent by 2020 and 25 percent by 2025. The benefits associated with fuel cell vehicles were derived by comparing the amount of fuel cell vehicles from the case with "both Hydrogen and Vehicle Technologies" to the "Vehicle Technologies only" case. Analysts computed energy savings, oil savings, and carbon emission reductions, based on the incremental fuel cell vehicles assuming conventional gasoline vehicle displacement (**see Figure 4.2**). This leads to greater savings than a simple difference between the cases, while still having smaller savings than would be derived by comparing a fuel cell vehicles case with the Baseline Case. **Table 4.11** presents the overall benefits.

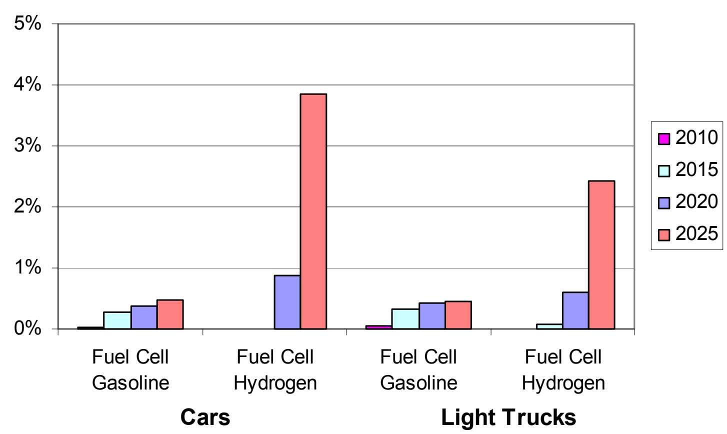


Figure 4.2. Vehicle Shares

Table 4.11. FY05 Benefits Estimates for Hydrogen, Fuel Cells, and Infrastructure Technologies Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.01	0.06	0.14	0.49
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	0.0	0.3	1.3	5.2
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.0	1.3	3.6	11.8
Security				
Oil Savings (mbpd)	ns	ns	0.10	0.40
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	-0.13	-0.42
Avoided Additions to Central Conventional Power (gigawatts)	0	0	1	0
Program-Specific Electric Capacity Additions (gigawatts)	0	1	2	2

Industrial Technologies Program

The Industrial Technologies Program covers primarily the energy-intensive basic materials processing industries, as well as some key technologies that are common across most industries, with the objective of increasing energy efficiency. These can be characterized in two categories, R&D and deployment. The R&D projects generally apply to specific industries or to specific technologies that cut across industries. The R&D projects seek to develop new or improved technologies that are more energy efficient and more cost-effective than the alternatives currently available. The deployment projects seek to increase the adoption of existing, as well as new, energy-efficient technologies.

The heterogeneity of the program makes it difficult to represent the program activities explicitly through technologies in the NEMS-GPRA05 framework. Therefore, analysts perform an off-line analysis using detailed spreadsheet models, and use the resulting energy savings by fuel type to provide inputs into the integrated model. Because these programs cannot be modeled on an economic basis, analysts reduce the off-line energy savings by an "integration factor" before putting them into NEMS-GPRA05. This is to account for interactions among programs and feedback effects that could not be considered in their original estimation. The amount of the integration factor is based on how much program overlap or "integration" was captured by the off-line tools. The reduction is based on the expert judgment of the benefits analysis team. The three basic types of industrial programs were treated somewhat differently. Analysts reduced the Industries of the Future programs only 15 percent, because they are relatively specific and the least likely to experience overlap with other industrial programs. The crosscutting programs were reduced by 30 percent. The Best Practices activity initially was reduced by 50 percent. However, the program revised the Best Practices savings estimate, and the equivalent final reduction is roughly 35 percent.

Analysts then run the fully integrated NEMS-GPRA05 to compute the benefits metrics of primary energy savings, carbon emission reductions, and energy-expenditure savings that are associated with the fuel-consumption reductions.

The resulting estimated primary savings are slightly lower than those targeted because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, the lower energy consumption causes lower energy prices (although the feedback is small), which causes energy consumption to be higher than it otherwise would have been, leading to slightly lower program savings (**Table 4.12**).

Table 4.12. FY05 Benefits Estimates for Industrial Technologies Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.48	0.92	1.56	2.02
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	4.6	10.3	16.6	15.8
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	9.0	17.7	29.8	41.4
Security				
Oil Savings (mbpd)	0.10	0.10	0.10	0.20
Natural Gas Savings (quadrillion Btu/yr)	0.19	0.39	0.71	0.63
Avoided Additions to Central Conventional Power (gigawatts)	2	3	8	13
Total Electric Capacity Avoided (gigawatts)	3	2	8	15

Solar Energy Technologies Program

The Solar Energy Technologies Program develops both thermal-heat and electric-solar technologies. The solar water-heating component is focused on developing low-cost solar hot water and pool heaters to displace fossil-fueled or electric alternatives. For electricity generation, photovoltaics (PVs) are being improved for both distributed and central generation applications, and the program is working to accelerate PV adoption through the Million Solar Roofs Initiative. Concentrated Solar Power R&D also has been part of the Solar Energy Technologies Program, but is not included in the FY05 budget request. As a result, concentrated solar power has not been included in the GPRA05 benefits estimates.

The benefits for solar water heat are represented within the residential module of NEMS-GPRA05. The solar water heater is a specific technology defined by its capital cost, O&M costs, and electrical use. NEMS-GPRA05 was modified to add solar water heat as an option for new homes, and the algorithm governing water-heater replacements was modified so that solar water heaters could compete in a larger market. In the Program Case, the baseline assumptions were modified to reflect the program cost and performance goals. The costs were changed for both new and replacement water heaters.

Three changes were made to the representation of distributed PV systems in the Baseline and Program Cases. The size of the typical distributed PV installation was increased to 4 kW per home (from 2 kW) and to 100 kW per commercial building (from 10 kW) to reflect literature on recent installations. In addition, the fraction of eligible buildings was increased from 30 percent to 60 percent for homes and to 55 percent for commercial buildings. The California renewable energy credit program, which provides a PV credit of $4000/kW in 2003 declining by $40/kW per year, was included for the Pacific region. For the program case, the capital and O&M costs were modified to reflect the program's goals. The regional capacity factors in the Baseline Case were similar to those in the program's goals, so they were left unchanged.

In addition to competing on an economic basis with other electricity-generation technologies, PVs may be constructed for their environmental benefits. PERI, using their Green Power Market Model, provided an estimate of PV capacity additions in response to the expanding green power markets in many places throughout the country. The projections for green power PV installations were combined with the Million Solar Roofs Initiative goals (see **Table 4.13**) to determine the planned PV capacity additions that were incorporated into NEMS-GPRA05.

Table 4.13. NEMS-GPRA05 Solar Capacity (GW) and Water Heaters

Photovoltaics	2010	2015	2020	2025
GPRA Base				
Central PV	0.1	0.2	0.3	0.4
Distributed PV	0.6	0.6	2.1	9.0
Total	1.2	1.3	2.9	9.9
Solar Program Case				
Central PV	0.3	0.6	0.9	1.2
Distributed PV	1.5	4.1	12.2	24.9
Total	2.2	5.2	13.6	26.5
Incremental Capacity				
Central PV	0.2	0.4	0.6	0.8
Distributed PV	0.8	3.5	10.1	15.9
Total	1.1	4.0	10.8	16.7
Incremental Generation (BkWh)				
Central PV	0.5	1.0	1.5	1.8
Distributed PV	1.7	7.2	20.7	32.0
Total	2.2	8.2	22.2	33.8

Solar Water Heaters	2010	2015	2020	2025
GPRA Base				
Million	0.56	0.77	1.01	1.39
Share (percent)	0.5%	0.6%	0.8%	1.1%
Solar Program Case				
Million	1.98	5.23	8.49	12.47
Share (percent)	1.7%	4.3%	6.7%	9.4%

Estimates of primary energy, oil, and carbon emissions savings result from displacement of energy use for water and pool heating, and from electricity demand reductions and PV generation. The savings associated with reduced electricity requirements depend on which types of generating plants were built and operated in the Baseline Case. Over time, the mix of fuels and efficiencies of power generation vary; and, therefore, the energy savings will as well. Energy-expenditure savings are measured as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers. Energy savings from water heaters also directly reduce energy expenditures. Overall benefits of the Solar Energy Technologies Program are shown in **Table 4.14**.

Table 4.14. FY05 Benefits Estimates for Solar Energy Technology Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.04	0.12	0.23	0.42
Generation (gigawatt-hours/yr)	2	8	22	34
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	0.2	1.2	6.6	4.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	0.9	2.0	4.7	9.0
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.00	0.10	0.10	0.15
Avoided Additions to Central Conventional Power (gigawatts)	1	3	8	10
Program-Specific Electric Capacity Additions (gigawatts)	1	4	11	17

Vehicle Technologies Program

The Vehicle Technologies Program[8] consists of research on light-vehicle hybrid and diesel technologies, heavy-vehicle and parasitic loss-reduction technologies, and lightweight materials for engines and vehicles. In addition, the program includes research in advanced petroleum and renewable fuels.

Light-vehicle hybrid and diesel technologies: This research aims to improve engine technologies in light-duty vehicles, which include passenger cars and light-duty trucks. Analysts compute benefits estimates for these activities through a process that estimates the penetration (sales) of the various technologies in the market for light-duty vehicles over time. The amount that each technology penetrates into the market determines the stock of these vehicles and the vehicle miles traveled (VMT) associated with each technology.

Heavy-vehicle and parasitic loss-reduction technologies: Heavy vehicles are those that have a gross weight (the weight when fully loaded) of 10,000 pounds or more. The benefits of this R&D

[8] The Vehicle Technologies Program is run by the Office of FreedomCAR and Vehicle Technologies.

activity are derived from penetration rates estimated by the Heavy Vehicle Model developed for the Vehicle Technologies Program, using efficiency and technology cost assumptions.

Lightweight materials for engines and vehicles: The lightweight materials developed under this R&D activity are used in both light and heavy vehicles. The benefits estimates for material are proportional to the percent of the fuel economy gain in light vehicles that is due to weight reduction. The benefits from weight reduction for heavy vehicles will be estimated in the future, but they are not in the current estimates.

In the NEMS-GPRA05 integrating model, the light-duty vehicle (LDV) market consists of six car classes—mini-compact, subcompact, compact, midsize, large, two-seater—and six light-duty truck classes—small and large pickup, small and large van, small and large sport utility vehicle (SUV)—in nine Census divisions. For each vehicle type and class and for each region, a number of LDV technologies compete against each other in the market for vehicle sales. These include conventional gasoline, advanced combustion diesel, gasoline hybrids, diesel hybrids, hydrogen internal combustion engine, gasoline fuel cell, hydrogen fuel cell, electric, natural gas, and alcohol. Each vehicle technology is represented by a number of characteristics that can change over the forecast time horizon and that influence the technology's acceptance in the marketplace (*i.e.*, its sales). These characteristics include the vehicle cost, the fuel cost per mile (a combination of the fuel price and the vehicle efficiency), the vehicle range, the operating and maintenance cost, the acceleration, the luggage space, the fuel availability, and the make and model availability. The NEMS-GPRA05 model also includes "calibration" coefficients to calibrate the model to historical data. The associated characteristics for all the "nonconventional" technologies are specified as relative to those for the conventional gasoline vehicle.

The model estimates the sales-penetration share of each technology in all of the vehicles, classes, and regions in each year of the forecast. The various characteristics of the technologies determine the technology's acceptance in the marketplace, but each characteristic has a differing degree of influence.[9] The vehicle cost is generally the most influential of the characteristics, certainly having a much stronger influence than luggage space for example. All the technologies are competed against each other using a nested logit formulation. In a logit formulation, the sum of all the influences from the characteristics for each technology is the "utility" for that technology, and the relative sizes of the "utility" for each technology determines the relative penetration shares for that technology. Technologies that have higher "utilities" are given greater sales shares. The overall sales-penetration results are the sum of all the more disaggregated results.

In the FY 2005 benefits analysis, the Baseline Case for transportation programs is essentially the *AEO2003* Reference Case, which already includes some small amount of penetration for the program vehicle technologies. The Program Case uses the program technology characteristics, along with a variety of other assumptions relating to behavioral responses in the underlying logit formulation of the NEMS-GPRA05 model. These include moving away from the "calibration"

[9] The vehicle shares are sensitive to assumptions about consumer preference for each vehicle attribute. In the NEMS-GPRA05 transportation model, a different set of consumer-choice assumptions is made than those in the NEMS *AEO2003* transportation model, leading to different rates of technology adoption.

coefficients over the forecast period (used by the model for a tie to history), and reworking the manner in which the make and model availability coefficients are used.

Using the fully integrated NEMS-GPRA05 model, the overall sales share for gasoline vehicles in 2025 falls from 80 percent in the Baseline Case to 38 percent in the Program Case (**Figure 4.3**). This decrease in share is due to the penetration of the alternative technologies. The overall share in 2025 for advanced combustion diesel increases from 4 percent to 24 percent, for gasoline hybrids from 9 percent to 19 percent, and for diesel hybrids from 1 percent to 14 percent.

These large-vehicle sales shares for advanced technology vehicles in 2025, however, translate into much smaller shares of overall vehicle stocks and overall shares of vehicle miles traveled (VMT) for each technology. The stock shares depend on the share of sales over time, which only gradually increases for the alternative-technology vehicles, and the rate of vehicle replacement and growth. The total VMT for gasoline vehicles falls from 3,367 billion miles in 2025 to 2,516 billion miles (about 60 percent of the VMT) between the two cases (**Figure 4.4**). The total VMT for advanced combustion diesel increases from 151 to 467 billion miles (11 percent), for diesel hybrids from 18 to 300 billion miles (6 percent), and for gasoline hybrids from 295 to 685 billion miles (16 percent).

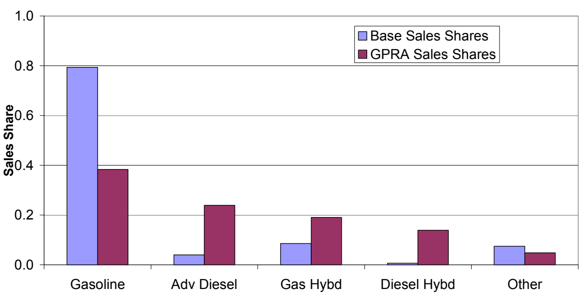


Figure 4.3. Sales Shares in 2025

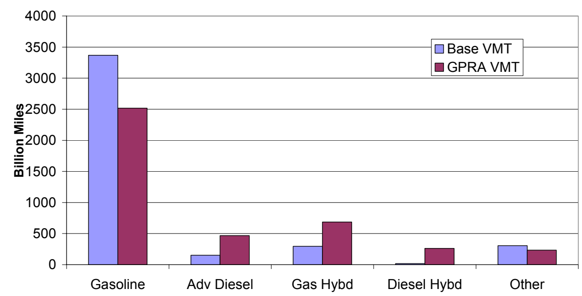


Figure 4.4. Vehicle Miles Traveled in 2025

The miles per gallon (MPG) for advanced combustion diesel and for hybrid vehicles is much greater than the MPG for conventional gasoline vehicles. As a consequence, since these advanced-technology vehicles are substituting for the conventional gasoline vehicles, there is a considerable amount of fuel savings.

In these fully integrated NEMS-GPRA05 model runs, the savings are typically somewhat less than if they were estimated in a transportation-only model, because of feedback effects that come through the integration with other sectors. The primary feedback effect occurs through lower fuel prices. In this case, reduced gasoline demand causes lower gasoline prices, which leads to an increase in travel and less-efficient vehicle purchases than would otherwise have occurred absent the price change. The rebound of gasoline consumption reduces the program savings. At the same time, energy-expenditure savings are greater. The small decreases in price apply to the total amount of fuel consumed and contribute significant additional expenditure savings. In addition, the "rebound" effect is also influenced by the fact that vehicles are more efficient, thereby reducing the cost to drive, causing more miles to be driven. **Table 4.15** presents the total program benefits, including those of heavy trucks.

Table 4.15. FY05 Benefits Estimates for Vehicle Technologies Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.19	0.65	1.55	2.94
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	6.4	9.0	27.5	55.5
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	4	13	29	54
Security				
Oil Savings (mbpd)	0.08	0.27	0.67	1.39
Natural Gas Savings (quadrillion Btu/yr)	ns	ns	ns	-0.10
Avoided Additions to Central Conventional Power (gigawatts)	ns	ns	ns	ns

Weatherization and Intergovernmental Program

The Weatherization and Intergovernmental Program (WIP) encompasses a broad range of activities in virtually all demand sectors of the energy economy. These activities generally are comprised of market enhancement, rather than R&D. The major components include: International, Native American Renewable Initiative (also referred to as Tribal Energy), Weatherization (Assistance), State and Community Grants, and Gateway Deployment (Energy Star, Clean Cities, Inventions and Innovations, and building codes). The FY 2005 benefits estimate methodologies vary by activity.

The international activities are currently outside the scope of the integrated modeling framework. The Native American renewable initiative also is not being modeled for this year. Weatherization and State and Community grants are implementation programs that lead to greater adoption of energy efficiency. They are represented by reducing energy consumption in the residential sector, based on the program goals.

The Clean Cities subprogram is represented through an increase in alternative-fuel vehicles. Analysts determined the cumulative number of expected vehicles participating in Clean Cities through off-line analysis. These were converted to annual vehicle sales and used as inputs into NEMS-GPRA05. The incremental sales were allocated to vehicle types, based on program information, although the fuel types in the model do not directly correspond in all cases. The largest share of vehicles are compressed natural gas, ethanol, and liquefied petroleum gas. Electric and methanol vehicle shares are small.

The Inventions and Innovation (I&I) subprogram savings estimates are based on numerous individual technologies receiving grants in the previous year, because this is the most recent year of award data available for analysis. For this analysis, the projects with the greatest expected energy savings are represented using specific technology characteristics or by targeting the energy-savings goals of the individual projects funded. This year, the technologies include two inventions involving ethanol production, two buildings equipment, and one industrial process. The ethanol and industrial process inventions could not be modeled on an economic basis within NEMS-GPRA05, so the estimated off-line energy savings were used in the model after being discounted by 30 percent to 50 percent to reflect potential interactions with other EERE markets and technologies. This discounting is comparable to that used for the Industrial Technologies Program. In the building sector, the electrochromic windows reduce heating and cooling loads. Based on an analysis performed by PNNL,[10] the windows were modeled in NEMS-GPRA05 based on technology cost and efficiency characteristics. The humidity-control invention was modeled using an assumption of air-conditioning savings in homes with commercial applications and in the markets where humidity control is important.

Analysts represented the Energy Star activities of Gateway Deployment by modifying the consumer-behavior coefficients, indicating how consumers trade first-cost expenditures for annual energy savings. The program goals for market penetration were used to determine the degree of change of these parameters. For the compact fluorescent bulb (CFL) activities, the target market share was defined as the fraction of lighting demand rather than the fraction of bulbs, in order to reflect that CFLs are most likely to be installed in high-use fixtures. The other component of Gateway Deployment is a portion of the savings associated with the upgrading of building codes. Because the other portion of the building code savings are attributed to the Building Technologies Program, the entire code effort was modeled as part of the Building Technologies Program, and then a fraction based on the program estimates was allocated to WIP. Overall benefits for WIP are shown in **Table 4.16**.

Table 4.16. FY05 Benefits Estimates for Weatherization and Intergovernmental Program (NEMS-GPRA05)

Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.42	0.67	0.90	1.08
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	5.2	7.7	10.9	16.8
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	8.2	13.3	19.1	24.3
Security				
Oil Savings (mbpd)	0.00	0.00	0.10	0.10
Natural Gas Savings (quadrillion Btu/yr)	0.19	0.29	0.29	0.23
Avoided Additions to Central Conventional Power (gigawatts)	4	8	10	9
Total Electric Capacity Avoided (gigawatts)	6	11	11	13

Wind and Hydropower Technologies Program

The wind component of the Wind and Hydropower Technologies Program seeks to reduce the cost—and improve the performance—of wind generation. The FY05 benefits are based primarily on projecting the market share for wind technologies, based on their economic characteristics.

The hydropower subprogram goal is to reduce the environmental impact of hydroelectric facilities. Because this program is driven more by environmental than economic concerns, off-

[10] See Appendix K on the Weatherization and Intergovernmental Program analysis.

line analysis provided the market-penetration estimates for incremental capacity and generation that are the primary source for the FY 2005 benefits estimates.

Representation of Wind: The NEMS-GPRA05 electricity-sector module performs an economic analysis of alternative technologies in each of 13 regions. Within each region, new capacity is selected based on its relative capital and operating costs, its operating performance (*i.e.*, availability), the regional load requirements, and existing capacity resources. Unlike the *AEO2003* version of NEMS, NEMS-GPRA05 characterizes wind by three wind classes, which each have their own capital costs and resource cost multipliers. For example, wind turbines being developed by the program for use in Class 4 winds are expected to be more expensive, but deliver more electricity per unit of capacity. The regional resource cost multipliers act to increase costs as more of a wind class is developed in a region, and development may move to the next most cost-effective wind class. The same resource multipliers are used as in the *AEO2003*, although they are applied at the class level rather than for the entire regional resource. Other key assumptions that can affect projections include a limit on the share of generation in each region that can be met with intermittent technologies.[11] NEMS-GPRA05, as in the *AEO2003*, assumes that the capacity value of wind diminishes with greater wind capacity in a region. Finally, another constraint on the growth of wind-resource development is how quickly the wind industry can expand before costs increase due to manufacturing bottlenecks. The *AEO2003* assumption that a cost premium is imposed when new orders exceed 50 percent of installed capacity was maintained for the Program Case analysis (see **Table 4.17**).

Table 4.17. Wind Capacity (GW)

		2010	2015	2020	2025
AEO Base		8.5	10.1	11.0	12.0
GPRA Baseline					
By Wind Class	Class 6	3.1	3.3	3.3	3.3
	Class 5	1.4	1.7	1.7	1.7
	Class 4	3.4	3.7	4.0	4.0
	Total	7.9	8.7	9.0	9.1
Wind Program Case					
By Wind Class	Class 6	4.2	7.5	9.3	9.3
	Class 5	5.1	5.5	5.5	5.9
	Class 4	5.3	19.3	49.1	52.5
	Total	14.6	32.3	63.9	67.7
Incremental Capacity					
By Wind Class	Class 6	1.0	4.2	6.0	6.0
	Class 5	3.7	3.8	3.8	4.1
	Class 4	1.9	15.6	45.1	48.5
	Total	6.7	23.6	54.9	58.6

Analysts represented the Wind Program R&D activities by reducing the capital and O&M costs and increasing the performance of wind capacity to match the program cost goals. In addition to competing on an economic basis with other electricity-generation technologies, wind capacity

[11] The *AEO2003* assumption that wind may provide only a maximum of 20 percent of a region's generation was maintained although the program disagrees with that characterization.

may be constructed for its environmental benefit. PERI, using their Green Power Market Model, provided an estimate of wind capacity additions in response to the expanding green power markets in many places nationwide. Analysts incorporated the projections for green power wind installations into NEMS-GPRA05 as planned capacity additions.

Representation of Hydropower: Hydropower Program analysts expect that future hydroelectric capacity and generation may decrease due to environmental concerns as facilities undergo relicensing. The program goal is to develop hydro turbines that reduce fish mortality rates, and therefore reduce the risk of these capacity reductions. The *AEO2003* projected relatively constant hydropower, implying that the technology was assumed to be deployed already or that the issue had not been examined. As a result, the Baseline Case was modified to reflect a loss of 6 percent of hydro capacity and generation by 2025 in the absence of the fish-friendly turbines. The Program Case then returned hydropower to the prior constant levels, and the forecast benefits result from the increased hydroelectric output.

The program is also working on methods to optimize generation from hydroelectric facilities and provide additional electricity with little capital investment. The program's goal of increasing generation from existing facilities up to 6 percent by 2020 was incorporated in NEMS-GPRA05 by increasing the hydro capacity factors.

Table 4.18 provides the estimates of primary energy, oil, and carbon emissions savings stemming from wind and hydropower displacing fossil-fueled generation sources. Analysts measure the energy-expenditure savings as the reduction in consumer expenditures for electricity and other fuels. Lower-cost renewable generation options reduce the price of electricity directly and reduce the pressure on natural gas supply, both of which benefit end-use consumers.

Table 4.18. FY05 Benefits Estimates for Wind and Hydropower Technologies Program (NEMS-GPRA05)

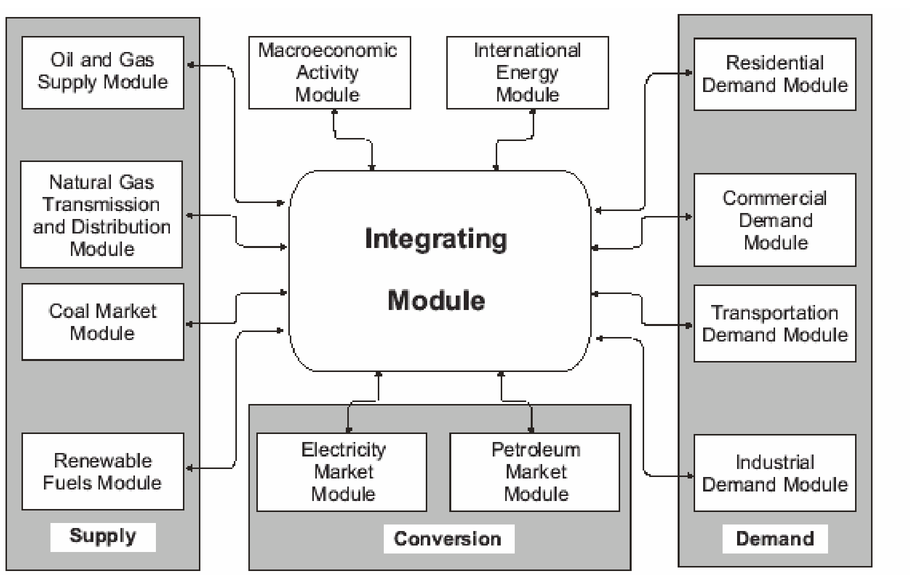
Benefits	2010	2015	2020	2025
Energy Displaced				
Nonrenewable Energy Savings (quadrillion Btu/yr)	0.27	0.79	1.65	1.77
Generation (gigawatt-hours/yr)	41	105	232	248
Economic				
Energy-Expenditure Savings (billion 2001 dollars/yr)	1.1	4.2	12.0	3.9
Environmental				
Carbon Savings (million metric tons carbon equivalent/yr)	5.6	16.1	32.7	38.9
Security				
Oil Savings (mbpd)	ns	ns	ns	ns
Natural Gas Savings (quadrillion Btu/yr)	0.12	0.37	0.84	0.57
Avoided Additions to Central Conventional Power (gigawatts)	6	9	13	20
Program-Specific Electric Capacity Additions (gigawatts)	10	28	59	63

Box 4.1—EIA's National Energy Modeling System (NEMS)*

The National Energy Modeling System (NEMS) is an energy-economy modeling system of U.S. energy markets for the midterm period through 2025. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE). As described in the GPRA Baseline section, the NEMS-GPRA05 version of the model used for the EERE GPRA analysis includes minor modifications to the standard EIA NEMS.

NEMS is designed as a modular system. Four end-use demand modules represent fuel consumption in the residential, commercial, transportation, and industrial sectors; subject to delivered fuel prices, macroeconomic influences, and technology characteristics. The primary fuel supply and conversion modules compute the levels of domestic production, imports, transportation costs, and fuel prices that are needed to meet domestic and export demands for energy; subject to resource base characteristics, industry infrastructure and technology, and world market conditions. The modules interact to solve for the economic supply and demand balance for each fuel. Because of the modular design, each sector can be represented with the methodology and the level of detail (including regional detail) that is appropriate for that sector.

A key feature of NEMS is the representation of technology and technology improvement over time. Five of the sectors—residential, commercial, transportation, electricity generation, and refining—include extensive treatment of individual technologies and their characteristics, such as the initial capital cost, operating cost, date of availability, efficiency, and other characteristics specific to the sector. Technological progress results in a gradual reduction in cost and is modeled as a function of time in these end-use sectors. In addition, the electricity sector accounts for technological optimism in the capital costs of first-of-a-kind generating technologies and for a decline in cost as experience with the technologies is gained both domestically and internationally. In each of these sectors, equipment choices are made for individual technologies as new equipment is needed to meet growing demand for energy services or to replace retired equipment. In the other sectors—industrial, oil and gas supply, and coal supply—the treatment of technologies is more limited, due to a lack of data on individual technologies. In the industrial sector, only the combined heat and power and motor technologies are explicitly considered and characterized. Cost reductions resulting from technological progress in combined heat and power technologies are represented as a function of time as experience with the technologies grows. Technological progress is not explicitly modeled for the industrial motor technologies. Other technologies in the energy-intensive industries are represented by technology bundles, with technology possibility curves representing efficiency improvement over time. In the oil and gas supply sector, technological progress is represented by econometrically estimated improvements in finding rates, success rates, and costs. Productivity improvements over time represent technological progress in coal production.



* Most of this description is taken from *The National Energy Modeling System: An Overview 2003*, DOE/EIA-0581(2003), March 2003.