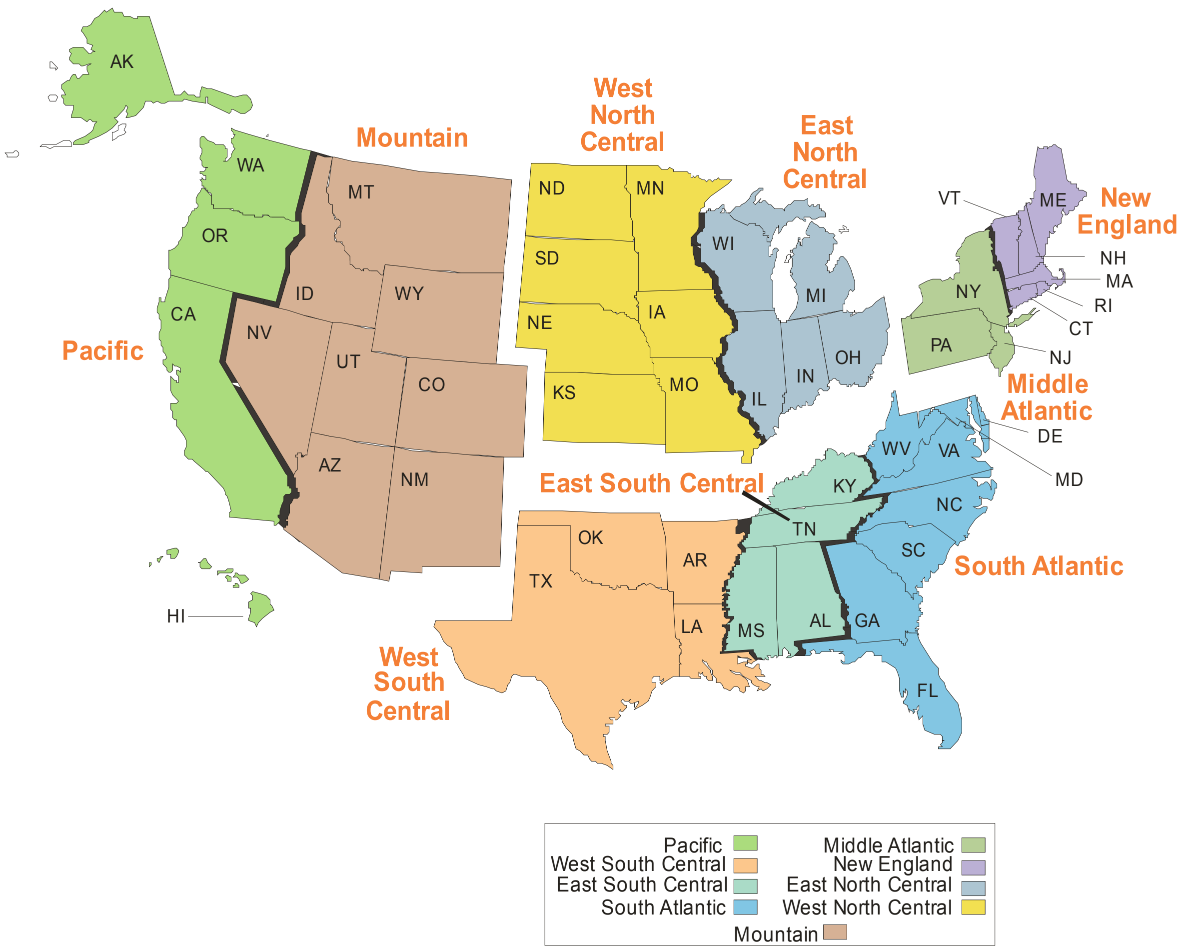
Residential Demand Module

The NEMS Residential Demand Module projects future residential sector energy requirements based on projections of the number of households and the stock, efficiency, and intensity of energy-consuming equipment. The Residential Demand Module projections begin with a base year estimate of the housing stock, the types and numbers of energy-consuming appliances servicing the stock, and the "unit energy consumption" (UEC) by appliance (in million Btu per household per year). The projection process adds new housing units to the stock, determines the equipment installed in new units, retires existing housing units, and retires and replaces appliances. The primary exogenous drivers for the module are housing starts by type (single-family, multifamily and mobile homes) and by Census Division, and prices for each energy source for each of the nine Census Divisions (see Figure 5).

The Residential Demand Module also requires projections of available equipment and their installed costs over the projection horizon. Over time, equipment efficiency tends to increase because of general technological advances and also because of Federal and/or State efficiency standards. As energy prices and available equipment change over the projection horizon, the module includes projected changes to the type and efficiency of equipment purchased as well as projected changes in the usage intensity of the equipment stock.

Figure 5. United States Census Divisions



Source: U.S. Energy Information Administration, Office of Energy Analysis.

The end-use services for which equipment stocks are modeled include space conditioning (heating and cooling), water heating, refrigeration, freezers, dishwashers, clothes washers, lighting, furnace fans, color televisions, personal computers, cooking, clothes drying, ceiling fans, coffee makers, spas, home security systems, microwave ovens, set-top boxes, home audio equipment, rechargeable electronics, dehumidifiers, external power supplies, and VCR/DVDs. In addition to the major equipment-driven end-uses, the average energy consumption per household is projected for other electric and nonelectric appliances. The module's output includes number of households, equipment stock, average equipment efficiencies, and energy consumed by service, fuel, and geographic location. The fuels represented are distillate fuel oil, liquefied petroleum gas, natural gas, kerosene, electricity, wood, coal, geothermal, and solar energy.

One of the implicit assumptions embodied in the Residential Demand Module is that, through 2035, there will be no radical changes in technology or consumer behavior. With the exception of efficiency levels described in consensus agreements among equipment manufacturers and efficiency advocates, no new regulations of efficiency beyond those currently embodied in law or new government programs fostering efficiency improvements are assumed. Technologies which have not gained widespread acceptance today will generally not achieve significant penetration by 2035. Currently available technologies will evolve in both efficiency and cost. In general, at the same efficiency level, future technologies will be less expensive, in real dollar terms, than those available today. When choosing new or replacement technologies, consumers will behave similarly to the way they now behave. The intensity of end uses will change moderately in response to price changes. Electric end uses will continue to expand, but at a decreasing rate [1].

Key assumptions

Housing Stock submodule

An important determinant of future energy consumption is the projected number of households. Base year estimates for 2005 are derived from the Energy Information Administration's (EIA) Residential Energy Consumption Survey (RECS) (Table 4.1). The projection for occupied households is done separately for each Census Division. It is based on the combination of the previous year's surviving stock with projected housing starts provided by the NEMS Macroeconomic Activity Module. The Housing Stock submodule assumes a constant survival rate (the percentage of households which are present in the current projection year, which were also present in the preceding year) for each type of housing unit; 99.6 percent for single-family units, 99.9 percent for multifamily units, and 97.6 percent for mobile home units.

Projected fuel consumption is dependent not only on the projected number of housing units, but also on the type and geographic distribution of the houses. The intensity of space heating energy use varies greatly across the various climate zones in the United States. Also, fuel prevalence varies across the country—oil (distillate) is more frequently used as a heating fuel in the New England and Middle Atlantic Census Divisions than in the rest of the country, while natural gas dominates in the Midwest. An example of differences by housing type is the more prevalent use of liquefied petroleum gas in mobile homes relative to other housing types.

Table 4.1. 2005 Households

Census	Single-Family Units	Multifamily Units	Mobile Homes	Total Units
New England	3,382,964	1,899,961	173,072	5,465,996
Middle Atlantic	10,077,231	4,794,686	254,610	15,116,527
East North Central	14,091,216	3,233,929	424,271	17,749,416
West North Central	6,107,582	1,406,214	340,759	7,854,555
South Atlantic	14,823,660	4,910,592	1,962,563	21,696,715
East South Central	5,438,660	729,591	724,503	6,892,754
West South Central	8,892,255	2,120,675	1,109,901	12,122,831
Mountain	5,680,398	951,482	922,976	7,554,856
Pacific	11,150,078	4,456,348	1,030,541	16,636,967
United States	79,653,923	24,493,498	6,943,196	111,090,617

Source: U.S. Energy Information Administration, 2005 Residential Energy Consumption Survey.

Technology Choice submodule

The key inputs for the Technology Choice submodule are fuel prices by Census Division and characteristics of available equipment (installed cost, maintenance cost, efficiency, and equipment life). The Integrating Module of NEMS estimates fuel prices through an equilibrium simulation that balances supply and demand and passes the prices to the Residential submodule.

Prices combined with equipment UEC (a function of efficiency) determine the operating costs of equipment. Equipment characteristics are exogenous to the model and are modified to reflect both Federal standards and anticipated changes in the market place. Table 4.2 lists capital costs and efficiency for selected residential appliances for the years 2010 and 2020.

Table 4.2. Installed cost and efficiency ratings of selected equipment

Equipment Type	Relative Performance[1]	2010 Installed Cost (2010$)[2]	2010 Efficiency[3]	2020 Installed Cost (2010$)[2]	2020 Efficiency[3]	Approximate Hurdle Rate
	Minimum	$4,800	7.7	$4,950	8.0	
Electric Heat Pump (heating component)	Best	$7,850	10.7	$8,200	10.8	25%
	Minimum	$2,500	0.78	$2,750	0.90	
Natural Gas Furnace[4]	Best	$2,625	0.98	$3,750	0.98	15%
	Minimum	$275	9.8	$295	11.0	
Room Air Conditioner	Best	$455	12.0	$515	13.0	42%
	Minimum	$3,200	13.7	$3,550	14.0	
Central Air Conditioner	Best	$4,500	21.0	$5,750	24.0	25%
	Minimum	$500	511	$525	408	
Refrigerator[5]	Best	$850	342	$1,250	327	10%
	Minimum	$600	0.90	$675	0.95	
Electric Water Heater	Best	$1,370	2.35	$2,050	2.35	50%
Solar Water Heater[6]	N/A	$5,320	N/A	$5,110	N/A	30%

[1]Minimum performance refers to the lowest-efficiency equipment available. Best refers to the highest-efficiency equipment available.
[2]Installed costs are given in 2010 dollars in the original source document.
[3]Efficiency measurements vary by equipment type. Electric heat pumps are based on Heating Seasonal Performance Factor (HSPF); natural gas furnaces are based on Annual Fuel Utilization Efficiency (AFUE); central air conditioners are based on Seasonal Energy Efficiency Ratio (SEER); room air conditioners are based on Energy Efficiency Ratio (EER); refrigerators are based on kilowatt-hours per year; and water heaters are based on Energy Factor (delivered Btu divided by input Btu).
[4]Values are for Northern regions of U.S.
[5].Reflects refrigerator with top mounted freezer with 20.6 cubic feet nominal volume.
[6]Values are for Southern regions of U.S.
Source: EIA Technology Forecast Updates, (Navigant Consulting , 2010).

Table 4.3 provides the cost and performance parameters for representative distributed generation technologies. The model also incorporates endogenous "learning" for the residential distributed generation technologies, allowing for declining technology costs as shipments increase. For fuel cell and photovoltaic systems, learning parameter assumptions for the Reference case result in a 13-percent reduction in capital costs each time the number of units shipped to the buildings sectors (residential and commercial) doubles. Capital costs for small wind, a relatively mature technology, only decline three percent with each doubling of shipments.

The Residential Demand Module projects equipment purchases based on a nested choice methodology. The first stage of the choice methodology determines the fuel and technology to be used. The equipment choices for cooling, water heating, and cooking are linked to the space heating choice for new construction. Technology and fuel choice for replacement equipment uses a nested methodology similar to that for new construction, but includes (in addition to the capital and installation costs of the equipment) explicit costs for fuel or technology switching (e.g., costs for installing gas lines if switching from electricity or oil to gas, or costs for adding ductwork if switching from electric resistance heat to central heating types). Also, for replacements, there is no linking of fuel choice for water heating and cooking as is done for new construction. Technology switching across fuels upon replacement is allowed for space heating, air conditioning, water heating, cooking and clothes drying.

Once the fuel and technology choice for a particular end use is determined, the second stage of the choice methodology determines efficiency. In any given year, there are several available prototypes of varying efficiency (minimum standard, some intermediate levels, and highest efficiency). Efficiency choice is based on a functional form and coefficients which give greater or lesser importance to the installed capital cost (first cost) versus the operating cost. Generally, within a technology class, the higher the first cost, the lower the operating cost. For new construction, efficiency choices are made based on the costs of both the heating and cooling equipment and the building shell characteristics.

The parameters for the second stage efficiency choice are calibrated to the most recently available shipment data for the major residential appliances. Shipment efficiency data are obtained from industry associations which monitor shipments, such as the Association of Home Appliance Manufacturers. Because of this calibration procedure, the model allows the relative importance of first cost versus operating cost to vary by general technology and fuel type (e.g. natural gas furnace, electric heat pump, electric central air conditioner, etc.). Once the model is calibrated, it is possible to obtain calculations for the apparent discount rates based on the relative weight given to the operating cost savings versus the weight given to the higher initial cost of more efficient equipment.

Hurdle rates in excess of 30 percent are common in the Residential Demand Module. The prevalence of such high apparent hurdle rates by consumers has led to the notion of the "efficiency gap" — that is, there are many investments that could be made that provide rates of return in excess of residential borrowing rates (10 to 20 percent for example). There are several studies which document instances of apparent high discount rates [2]. Once equipment efficiencies for a technology and fuel are determined, the installed efficiency for its entire stock is calculated.

Appliance Stock submodule

The Appliance Stock submodule is an accounting framework which tracks the quantity and average efficiency of equipment by end use, technology, and fuel. It separately tracks equipment requirements for new construction and existing housing units. For existing units, this module calculates the number of units which survive from previous years, allows certain end uses to further penetrate into the existing housing stock and calculates the total number of units required for replacement and further penetration. Air conditioning and clothes drying are the two major end uses not considered to be "fully penetrated."

Table 4.3. Capital cost and performance parameters of selected residential distributed generation technologies

Technology Type	Year of Introduction	Average Generating Capacity (kW_{DC})	Electrical Efficiency	Combined Efficiency (Elec. + Thermal	Installed Capital Cost (2009 $ per kW_{DC})[1]	Service Life (Years)
Solar Photovoltaic						
	2010	3.5	0.150	N/A	$7,183	30
	2015	4.0	0.175	N/A	$5,346	30
	2025	5.0	0.197	N/A	$4,284	30
	2035	5.0	0.200	N/A	$4,048	30
Fuel Cell						
	2010	10	0.364	0.893	$14,837	20
	2015	10	0.429	0.859	$14,837	20
	2025	10	0.456	0.842	$14,837	20
	2035	10	0.479	0.828	$14,837	20
Wind						
	2010	2	0.13	N/A	$7,802	30
	2015	3	0.13	N/A	$6,983	30
	2025	3	0.13	N/A	$6,234	30
	2035	4	0.13	N/A	$5,903	30

[1]The original source documents presented solar photovoltaic costs in 2008 dollars, fuel cell and wind costs in 2010 dollars.
Source: Solar photovoltaic: Photovoltaic (PV) Cost and Performance Characteristics for Residential and Commercial Applications (ICF International, 2010). Fuel cell: Commercial and Industrial CHP Technology Cost and Performance Data Analysis for EIA (SENTECH Incorporated, 2010). Wind: The Cost and Performance of Distributed Wind Turbines, 2010-35 (ICF International, 2010).

Once a piece of equipment enters into the stock, an accounting of its remaining life begins. It is assumed that all appliances survive a minimum number of years, after which a fraction of appliances are removed from the stock. Between the minimum and maximum life expectancy, all appliances retire based on a linear decay function. For example, if an appliance has a minimum life of five years and a maximum life of 15 years, one-tenth of the units (one divided by 15 minus five) are retired in each of years six through 15. It is further assumed that, when a house is retired from the stock, all of the equipment contained in that house retires as well; i.e., there is no second-hand market for this equipment. The assumptions concerning equipment lives are in Table 4.4.

Table 4.4. Minimum and maximum life expectancies of equipment

Equipment	Minimum Life	Maximum Life
Heat Pumps	7	21
Central Forced-Air Furnaces	10	25
Hydronic Space Heaters	20	30
Room Air Conditioners	8	16
Central Air Conditioners	7	21
Gas Water Heaters	4	14
Electric Water Heaters	5	22
Cooking Stoves	16	21
Clothes Dryers	11	20
Refrigerators	7	26
Freezers	11	31

Source: Lawrence Berkeley National Laboratory. Baseline Data for the Residential Sector and Development of a Residential Forecasting Database, May 1994, and analysis of RECS 2001 data.

Fuel Consumption submodule

Energy consumption is calculated by multiplying the vintage equipment stocks by their respective UECs. The UECs include adjustments for the average efficiency of the stock vintages, short-term price elasticity of demand and "rebound" effects on usage (see discussion below), the size of new construction relative to the existing stock, people per household, shell efficiency and weather effects (space heating and cooling). The various levels of aggregated consumption (consumption by fuel, by service, etc.) are derived from these detailed equipment-specific calculations.

Equipment efficiency

The average energy consumption of a particular technology is initially based on estimates derived from RECS 2005. Appliance efficiency is either derived from a long history of shipment data (e.g., the efficiency of conventional air-source heat pumps) or assumed based on engineering information concerning typical installed equipment (e.g., the efficiency of ground-source heat pumps). When the average efficiency is computed from shipment data, shipments going back as far as 20 to 30 years are combined with assumptions concerning equipment lifetimes. This allows for not only an average efficiency to be calculated, but also for equipment to be vintaged and retirements to be projected by vintage and efficiency, as older equipment tends to be lower in efficiency and also tends to be retired before newer, more efficient equipment. Once equipment is retired, the Appliance Stock and Technology Choice Modules determine the efficiency of the replacement equipment. It is often the case that the retired equipment is replaced by substantially more efficient equipment.

As the stock efficiency changes over the simulation interval, energy consumption decreases in inverse proportion to efficiency. Also, as efficiency increases, the efficiency rebound effect (discussed below) will offset some of the reductions in energy consumption by increased demand for the end-use service. For example, if the stock average for electric heat pumps is now ten percent more efficient than in 2005, then all else constant (weather, real energy prices, shell efficiency, etc.), energy consumption per heat pump would average about only nine percent less.

Adjusting for the size of housing units

Information derived from RECS 2005 indicates that new construction (post-1990) is on average roughly 26 percent larger than the existing stock of housing. Estimates for the size of each new home built in the projection period vary by type and region, and are determined by a log-trend projection based on historical data from the Bureau of the Census [3]. For existing structures, it is assumed that about one percent of households that existed in 2005 add about 600 square feet to the heated floor space in each year of the projection period [4]. The energy consumption for space heating, air conditioning, and lighting is assumed to increase with the square footage of the structure. This results in an increase in the average size of a housing unit from 1,618 to 1,774 square feet from 2005 through 2035.

Adjusting for weather and climate

Weather in any given year always includes short-term deviations from the expected longer-term average (or climate). Recognition of the effect of weather on space heating and air conditioning is necessary to avoid inadvertently projecting abnormal weather conditions into the future. The residential module adjusts space heating and air conditioning UECs by Census Division using data on heating and cooling degree-days (HDD and CDD). A ten-percent increase in HDD would increase space heating consumption by ten percent over what it would have otherwise been. Over the projection period, the residential module uses a ten-year average for heating and cooling degree-days by Census Division, adjusted to account for projected changes population by State.

Short-term price effect and efficiency rebound

It is assumed that energy consumption for a given end-use service is affected by the marginal cost of providing that service. That is, all else equal, a change in the price of a fuel will have an opposite, but less than proportional, effect on fuel consumption. The current value for the short-term elasticity parameter for non-electric fuels is -0.15 [5]. This value implies that for a 1-percent increase in the price of a fuel, there will be a corresponding decrease in energy consumption of -0.15 percent. Changes in equipment efficiency also affect the marginal cost of providing a service. For example, a 10-percent increase in efficiency will reduce the cost of providing the end-use service by 10 percent. Based on the short-term efficiency rebound parameter, the demand for the service will rise by 1.5 percent (-10 percent multiplied by -0.15). Only space heating, cooling, and lighting are assumed to be affected by both elasticities and the efficiency rebound effect. For electricity, the short-term elasticity parameter is set to -0.30 to account for successful deployment of smart grid projects funded under the American Recovery and Reinvestment Act of 2009 (ARRA09).

Shell efficiency

The shell integrity of the building envelope is an important determinant of the heating and cooling load for each type of household. In the NEMS Residential Demand Module, the shell integrity is represented by an index, which changes over time to reflect improvements in the building shell. The shell integrity index is dimensioned by vintage of house, type of house, fuel type, service (heating and cooling), and Census Division. The age, type, location, and type of heating fuel are important factors in determining the level of shell integrity. Housing units heated with electricity tend to have less air infiltration rates than homes that use other fuels. Homes are classified by age as new (post-2005) or existing. Existing homes are represented by the RECS 2005 survey and are assigned a shell index value based on the mix of homes that exist in the base year (2005). The improvement over time in the shell integrity of these homes is a function of two factors—an assumed annual efficiency improvement and improvements made when real fuel prices increase (no price-related adjustment is made when fuel prices fall). For new construction, building shell efficiency is determined by the relative costs and energy bill savings for several levels of heating and cooling equipment, in conjunction with the building shell attributes. The packages represented in NEMS range from homes that meet the International Energy Conservation Code (IECC) [6] to homes that are built with the most efficient shell components. Shell efficiency in new homes increases over time when energy prices rise, or the cost of more efficient equipment falls, all else equal.

Legislation and regulations

American Recovery and Reinvestment Act of 2009 (ARRA09)

The ARRA09 legislation passed in February 2009 provides energy efficiency funding for Federal agencies, State Energy Programs, and block grants, as well as a sizable increase in funding for weatherization. To account for the impact of this funding, it is assumed that the total funding is aimed at increasing the efficiency of the existing housing stock. The assumptions regarding the energy savings for heating and cooling are based on evaluations of the impact of weatherization programs over time. Further, it is assumed each house requires a $2,600 investment to achieve the heating and cooling energy savings cited in [7] and that the efficiency measures last approximately 20 years. Assumptions for funding amounts and timing were revised downward and further into the future based on analysis of the weatherization program by the Inspector General of the Department of Energy [8].

The ARRA09 provisions remove the cap on the 30-percent tax credit for ground-source heat pumps, solar PV, solar thermal water heaters, and small wind turbines through 2016. Additionally, the cap for the tax credits for other energy efficiency improvements, such as windows and efficient furnaces, was increased to $1500 through the end of 2010. Several tax credits were extended at reduced credit levels through the end of 2011 as part of the Tax Relief, Unemployment Insurance Reauthorization, and Job Creation Act of 2010.

Successful deployment of smart grid projects based on ARRA09 funding could stimulate more rapid investment in smart grid technologies, especially smart meters on buildings and homes, which would make consumers more responsive to electricity price changes. To represent this, the price elasticity of demand for residential electricity was increased for the services that have the ability to alter energy intensity (e.g., lighting).

Energy Improvement and Extension Act of 2008 (EIEA 2008)

EIEA 2008 extends and amends many of the tax credits that were made available to residential consumers in EPACT 2005. The tax credits for energy-efficient equipment can now be claimed through 2016, while the $2000 cap for solar technologies has been removed. Additionally, the tax credit for ground-source (geothermal) heat pumps was increased to $2000. The production tax credits for dishwashers, clothes washers, and refrigerators were extended by one to two years, depending on the efficiency level and product. See the EPACT 2005 section below for more details about product coverage.

Energy Independence and Security Act of 2007 (EISA 2007)

EISA 2007 contains several provisions that impact projections of residential energy use. Standards for general service incandescent light bulbs are phased in over 2012-2014, with a more restrictive standard specified in 2020. It is estimated that these standards require 29 percent less watts per bulb in the first phase-in, increasing to 67 percent in 2020. EISA also updates the dehumidifier standard specified in EPACT 2005, resulting in a seven-percent increase in electricity savings relative to the EPACT 2005 requirement. New efficiency standards for external power supplies are set for July 1, 2008, reducing electricity use in both the active and no-load modes. Standards are also set for boilers (September 2012) and dishwashers (January 2010). Lastly, DOE is instructed to create standards for manufactured housing, requiring compliance to the latest International Energy Conservation Code (IECC) by the end of 2011.

Energy Policy Act of 2005 (EPACT05)

The passage of the EPACT05 in August 2005 provides additional minimum efficiency standards for residential equipment and provides tax credits to producers and purchasers of energy-efficient equipment and builders of energy-efficient homes. The standards contained in EPACT05 include: 190 watt maximum for torchiere lamps in 2006; dehumidifier standards for 2007 and 2012; and ceiling fan light kit standards in 2007. For manufactured homes that are 30 percent better than the latest code, a $1000 tax credit can be claimed in 2006 and 2007. Likewise, builders of homes that are 50 percent better than code can claim a $2000 credit over the same period. The builder tax credits and production tax credits are assumed to be passed through to the consumer in the form of lower purchase cost. EPACT05 includes production tax credits for energy-efficient refrigerators, dishwashers, and clothes washers in 2006 and 2007, with dollar amounts varying by type of appliance and level of efficiency met, subject to annual caps. Consumers can claim a 10 percent tax credit in 2006 and 2007 for several types of appliances specified by EPACT05, including: energy-efficient gas, propane, or oil furnaces or boilers, energy-efficient central air conditioners, air and ground source heat pumps, hot water heaters, and windows. Lastly, consumers can claim a 30 percent tax credit in 2006 and 2007 for purchases of solar PV, solar water heaters, and fuel cells, subject to a cap.

Residential alternative cases

Technology cases

In addition to the *AEO2012* Reference case, the Residential Demand Module contributes alternate assumptions to seven integrated side cases developed to examine the effect of different assumptions of technology and policy on energy use. Three cases are devoted to technology assumptions in the demand sectors: the 2011 Technology case, a High Technology case, and a Best Available Technology case. Two cases, the Integrated Low Technology and High Technology cases, combine demand sector technology assumptions with alternative technology assumptions for renewable and fossil fuel electricity generation technologies. Two cases examine policy continuation impacts: the No Sunset case and the Extended Policies case.

The 2011 Technology assumptions specify that all future equipment purchases are made based only on equipment available in 2011. These cases further assume that existing building shell efficiencies will not improve beyond 2011 levels. The 2011 Technology assumptions are implemented in the 2011 Integrated Demand Technology case and the Integrated Low Technology case.

The High Technology assumptions include earlier availability, lower costs, and/or higher efficiencies for more advanced equipment than the Reference case. Equipment assumptions developed by engineering technology experts reflect the potential impact on technology given increased research and development into more advanced technologies [9]. In the High Technology cases, all new construction is assumed to meet Energy Star specifications after 2016. In addition, consumers are assumed to evaluate energy efficiency investments at a discount rate of seven percent real. The High Technology assumptions are implemented in the Integrated High Demand Technology case and the Integrated High Technology case.

The Best Available Technology case assumptions require that all equipment purchases from 2012 forward are based on the highest available efficiency in the High Technology case in a particular modeled year, disregarding the economic costs of such a case. This case is designed to show how much the choice of the highest-efficiency equipment could affect energy consumption. In this case, all new construction is built to the most efficient specifications after 2011. In addition, consumers are assumed to evaluate energy efficiency investments at discount rate of seven percent real.

Policy cases

The No Sunset case assumes the extension of all existling energy policies and legislation that contain sunset provisions. For the residential sector, this primarily involves tax credits for distributed generation and efficient end-use equipment. The Extended Policy case assumes additional rounds of appliance standards for most end-use equipment while maintaining the No Sunset tax credit assumptions for distributed generation, solar water heaters, and geothermal heat pumps. Standard levels are established based on current Energy Star guidelines. The Extended Policy case also adds multiple rounds of building codes by 2026.

Notes and sources

[1] The Model Documentation Report contains additional details concerning model structure and operation. Refer to Energy Information Administration, Model Documentation Report: Residential Sector Demand Module of the National Energy Modeling System, DOE/EIA-M067(2011), (November 2011).

[2] Among the explanations often mentioned for observed high average implicit discount rates are: market failures, (i.e., cases where incentives are not properly aligned for markets to result in purchases based on energy economics alone); unmeasured technology costs (i.e., extra costs of adoption which are not included or difficult to measure, like employee down-time); characteristics of efficient technologies viewed as less desirable than their less-efficient alternatives (such as equipment noise levels or lighting quality characteristics); and the risk inherent in making irreversible investment decisions. Examples of market failures/barriers include: decision-makers having less than complete information, cases where energy equipment decisions are made by parties not responsible for energy bills (e.g., landlord/tenants, builders/home buyers), discount horizons which are truncated (which might be caused by mean occupancy times that are less than the simple payback time and that could possibly be classified as an information failure), and lack of appropriate credit vehicles for making efficiency investments. The use of high implicit discount rates in NEMS merely recognizes that such rates are typically found to apply to energy-efficiency investments.

[3] U.S. Bureau of Census, Series C25 Data from various years of publications.

[4] Sources: U.S. Bureau of Census, Annual Housing Survey 2001 and Professional Remodeler, 2002 Home Remodeling Study.

[5] See Dahl, Carol, A Survey of Energy Demand Elasticities in Support of the Development of the NEMS, October 1993.

[6] The IECC established guidelines for builders to meet specific targets concerning energy efficiency with respect to heating and cooling load.

[7] Oak Ridge National Laboratory, Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation Using Studies from 1993 to 2005, September 2005.

[8] U.S. Department of Energy, Office of Inspector General, Office of Audit Services, Special Report: Progress in Implementing the Department of Energy's Weatherization Assistance Program under the American Recovery and Reinvestment Act, February 2010.

[9] The high technology assumptions are based on Energy Information Administration, (*Technology Forecast Updates-Residential and Commercial Building Technologies-Advanced Adoption Case*) (Navigant Consulting, September 2011).

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