Appendix E

NEMS Overview and Brief Description of Cases

The National Energy Modeling System

Projections in the *Annual Energy Outlook 2010* (*AEO2010*) are generated from the National Energy Modeling System (NEMS) [*1*], developed and maintained by the Office of Integrated Analysis and Forecasting (OIAF) of the U.S. Energy Information Administration (EIA). In addition to its use in developing the *Annual Energy Outlook* (*AEO*) projections, NEMS is also used in analytical studies for the U.S. Congress, the Executive Office of the President, other offices within the U.S. Department of Energy (DOE), and other Federal agencies. The *AEO* projections are also used by analysts and planners in other government agencies and nongovernment organizations.

The projections in NEMS are developed with the use of a market-based approach to energy analysis. For each fuel and consuming sector, NEMS balances energy supply and demand, accounting for economic competition among the various energy fuels and sources. The time horizon of NEMS is the period through 2035, approximately 25 years into the future. In order to represent regional differences in energy markets, the component modules of NEMS function at the regional level: the nine Census divisions for the end-use demand modules; production regions specific to oil, natural gas, and coal supply and distribution; the North American Electric Reliability Council regions and subregions for electricity; and the Petroleum Administration for Defense Districts (PADDs) for refineries (see Appendix F for details).

NEMS is organized and implemented as a modular system. The modules represent each of the fuel supply markets, conversion sectors, and end-use consumption sectors of the energy system. NEMS also includes macroeconomic and international modules. The primary flows of information among the modules are the delivered prices of energy to end users and the quantities consumed, by product, region, and sector. The delivered fuel prices encompass all the activities necessary to produce, import, and transport fuels to end users. The information flows also include other data on such areas as economic activity, domestic production, and international liquids supply.

The Integrating Module controls the execution of each of the component modules. To facilitate modularity, the components do not pass information to each other directly but communicate through a central data structure. This modular design provides the capability to execute modules individually, thus allowing decentralized development of the system and independent analysis and testing of individual modules. The modular design also permits the use of the methodology and level of detail most appropriate for each energy sector. NEMS calls each supply, conversion, and end-use demand module in sequence until the delivered prices of energy and the quantities demanded have converged within tolerance, thus achieving an economic equilibrium of supply and demand in the consuming sectors. A solution is reached annually through the projection horizon. Other variables, such as petroleum product imports, crude oil imports, and several macroeconomic indicators, also are evaluated for convergence.

Each NEMS component represents the impacts and costs of legislation and environmental regulations that affect that sector. NEMS accounts for all combustion-related carbon dioxide (CO_2) emissions, as well as emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury from the electricity generation sector.

The version of NEMS used for *AEO2010* represents current legislation and environmental regulations as of October 31, 2009 (such as the American Recovery and Reinvestment Act of 2009 [ARRA], which was enacted in mid-February 2009; the Energy Improvement and Extension Act of 2008 [EIEA2008], signed into law on October 3, 2008; the Food, Conservation, and Energy Act of 2008; the Energy Independence and Security Act of 2007 [EISA2007], which was signed into law on December 19, 2007; the Energy Policy Act of 2005 [EPACT2005]; the Working Families Tax Relief Act of 2004; and the American Jobs Creation Act of 2004), and the costs of compliance with regulations (such as the new stationary diesel regulations issued by the U.S. Environmental Protection Agency [EPA] in July 2006). The *AEO2010* models do not represent the Clean Air Mercury Rule, which was vacated and remanded by the D.C. Circuit Court of the U.S. Court of Appeals on February 8, 2008, but they do represent State requirements for reduction of mercury emissions.

The *AEO2010* Reference case reflects the temporary reinstatement of the NO_x and SO_2 cap-and-trade programs included in the Clean Air Interstate Rule

(CAIR), according to the ruling issued by the U.S. Court of Appeals for the District of Columbia on December 23, 2008. The potential impacts of proposed Federal and State legislation, regulations, or standards—or of sections of legislation that have been enacted but require funds or implementing regulations that have not been provided or specified—are not reflected in NEMS.

In general, the historical data used for the *AEO2010* projections are based on EIA's *Annual Energy Review 2008*, published in June 2009 [*2*]; however, data were taken from multiple sources. In some cases, only partial or preliminary data were available for 2008. CO_2 emissions were calculated by using CO_2 coefficients from the EIA report, *Emissions of Greenhouse Gases in the United States 2008*, published in December 2009 [*3*]. Historical numbers are presented for comparison only and may be estimates. Source documents should be consulted for the official data values. Footnotes to the *AEO2010* appendix tables indicate the definitions and sources of historical data.

The *AEO2010* projections for 2009 and 2010 incorporate short-term projections from EIA's September 2009 *Short-Term Energy Outlook* (*STEO*). For short-term energy projections, readers are referred to monthly updates of the *STEO* [*4*].

Component modules

The component modules of NEMS represent the individual supply, demand, and conversion sectors of domestic energy markets and also include international and macroeconomic modules. In general, the modules interact through values representing the prices or expenditures for energy delivered to the consuming sectors and the quantities of end-use energy consumption.

Macroeconomic Activity Module

The Macroeconomic Activity Module (MAM) provides a set of macroeconomic drivers to the energy modules and receives energy-related indicators from the NEMS energy components as part of the macroeconomic feedback mechanism within NEMS. Key macroeconomic variables used in the energy modules include gross domestic product (GDP), disposable income, value of industrial shipments, new housing starts, sales of new light-duty vehicles (LDVs), interest rates, and employment. Key energy indicators fed back to the MAM include aggregate energy prices and costs. The MAM uses the following models from IHS Global Insight: Macroeconomic Model of the U.S. Economy, National Industry Model, and National Employment Model. In addition, EIA has constructed a Regional Economic and Industry Model to project regional economic drivers, and a Commercial Floorspace Model to project 13 floorspace types in 9 Census divisions. The accounting framework for industrial value of shipments uses the North American Industry Classification System (NAICS).

International Module

The International Energy Module (IEM) uses assumptions of economic growth and expectations of future U.S. and world petroleum liquids production and consumption, by year, to project the interaction of U.S. and international liquids markets. The IEM computes world oil prices, provides a world crude-like liquids supply curve, generates a worldwide oil supply/demand balance for each year of the projection period, and computes initial estimates of crude oil and light and heavy petroleum product imports for the United States.

The supply-curve calculations are based on historical market data and a world oil supply/demand balance, which is developed from reduced-form models of international liquids supply and demand, current investment trends in exploration and development, and long-term resource economics for 221 countries/territories. The oil production estimates include both conventional and unconventional supply recovery technologies. In the interaction with the rest of NEMS, the IEM changes the world oil price (WOP), which is defined as the price of foreign light, low sulfur crude oil delivered to Cushing, Oklahoma, (Petroleum Allocation Defense District 2), in response to changes in expected crude and product liquids produced and consumed in the United States.

Residential and Commercial Demand Modules

The Residential Demand Module projects energy consumption in the residential sector by housing type and end use, based on delivered energy prices, the menu of equipment available, the availability and cost of renewable sources of energy, and housing starts. The Commercial Demand Module projects energy consumption in the commercial sector by building type and nonbuilding uses of energy and by category of end use, based on delivered prices of energy, availability of renewable sources of energy, and macroeconomic variables representing interest rates and floorspace construction.

Both modules estimate the equipment stock for the major end-use services, incorporating assessments of advanced technologies, including representations of renewable energy technologies, and the effects of both building shell and appliance standards, including the recent regional standards for furnaces, heat pumps, and central air conditioners agreed to by manufacturers and environmental interest groups. The Commercial Demand Module incorporates combined heat and power (CHP) technology. The modules also include projections of distributed generation. Both modules incorporate changes to "normal" heating and cooling degree-days by Census division, based on a 10-year average and on State-level population projections. The Residential Demand Module projects an increase in the average square footage of both new construction and existing structures, based on trends in the size of new construction and the remodeling of existing homes.

Industrial Demand Module

The Industrial Demand Module projects the consumption of energy for heat and power, feedstocks, and raw materials in each of 21 industries, subject to the delivered prices of energy and the values of macroeconomic variables representing employment and the value of shipments for each industry. As noted in the description of the MAM, the value of shipments is based on NAICS. The industries are classified into three groups—energy-intensive manufacturing, non-energy-intensive manufacturing, and nonmanufacturing. Of the eight energy-intensive industries, seven are modeled in the Industrial Demand Module, with energy-consuming components for boiler/steam/cogeneration, buildings, and process/assembly use of energy.

A new bulk chemical model was implemented for the *AEO2010*. The new model calculates the production (in physical units), process shares, and process energy requirements for 26 specific chemicals and four aggregate groups of bulk chemicals. Details are included in the forthcoming Industrial Demand Module documentation. A generalized representation of CHP and a recycling component also are included. The use of energy for petroleum refining is modeled in the Petroleum Market Module (PMM), and the projected consumption is included in the industrial totals.

Transportation Demand Module

The Transportation Demand Module projects consumption of fuels in the transportation sector, including petroleum products, electricity, methanol, ethanol, compressed natural gas, and hydrogen, by transportation mode, vehicle vintage, and size class, subject to delivered prices of energy fuels and macroeconomic variables representing disposable personal income, GDP, population, interest rates, and industrial shipments. Fleet vehicles are represented separately to allow analysis of other legislation and legislative proposals specific to those market segments. The Transportation Demand Module also includes a component to assess the penetration of alternative-fuel vehicles. Provisions of EPACT2005, EIEA2008, and ARRA are reflected in the assessment of the impacts of tax credits on the purchase of hybrid gas-electric, plug-in electric, alternative-fuel, and fuel-cell vehicles. The corporate average fuel economy (CAFE) and biofuel representation in the module reflect standards proposed by the National Highway Traffic Safety Administration (NHTSA), the EPA, and provisions in EISA2007.

The air transportation component of the Transportation Demand Module explicitly represents air travel in domestic and foreign markets and includes the industry practice of parking aircraft in both domestic and international markets to reduce operating costs, as well as the movement of aging aircraft from passenger to cargo markets [*5*]. For passenger travel and air freight shipments, the module represents regional fuel use in regional, narrow-body, and wide-body aircraft. An infrastructure constraint, which is also modeled, can potentially limit overall growth in passenger and freight air travel to levels commensurate with industry-projected infrastructure expansion and capacity growth.

Electricity Market Module

There are three primary submodules of the Electricity Market Module—capacity planning, fuel dispatching, and finance and pricing. To project the optimal mix of new generation capacity that should be added in future years, the Capacity Planning Submodule uses the stock of existing generation capacity; the menu, cost, and performance of future generation capacity; expected fuel prices; expected financial parameters; expected electricity demand; and expected environmental regulations. The Fuel Dispatching Submodule uses the existing stock of generation equipment, their operating and maintenance (O&M) costs and performance, fuel prices to the electricity sector, electricity demand, and all applicable environmental regulations to determine the least-cost way to meet that demand; the submodule also

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projects transmission and pricing of electricity. The Finance and Pricing Submodule uses capital costs, fuel costs, macroeconomic parameters, and environmental regulations, along with load shapes, to estimate generation costs for each technology.

All specifically identified options promulgated by the EPA for compliance with the Clean Air Act Amendments of 1990 (CAAA90) are explicitly represented in the capacity expansion and dispatch decisions; those that have not been promulgated (e.g., fine particulate proposals) are not incorporated. All financial incentives for power generation expansion and dispatch specifically identified in EPACT2005 have been implemented. Several States, primarily in the Northeast, have recently enacted air emission regulations for CO_2 that affect the electricity generation sector, and those regulations are represented in *AEO2010*. The *AEO2010* Reference case reflects the temporary reinstatement of the NO_x and SO_2 cap-and-trade programs included in CAIR, as well as State regulations on mercury emissions.

Although currently there is no Federal legislation in place that restricts greenhouse gas (GHG) emissions, regulators and the investment community have continued to push energy companies to invest in technologies that are less GHG-intensive. The trend is captured in the *AEO2010* Reference case through a 3-percentage-point increase in the cost of capital when investments in new coal-fired power plants and new coal-to-liquids (CTL) plants without carbon capture and sequestration (CCS) are evaluated.

Renewable Fuels Module

The Renewable Fuels Module (RFM) includes submodules representing renewable resource supply and technology input information for central-station, grid-connected electricity generation technologies, including conventional hydroelectricity, biomass (dedicated biomass plants and co-firing in existing coal plants), geothermal, landfill gas, solar thermal electricity, photovoltaics (PV), and wind energy. The RFM contains renewable resource supply estimates representing the regional opportunities for renewable energy development. Investment tax credits (ITCs) for renewable fuels are incorporated, as currently enacted, including a permanent 10-percent ITC for business investment in solar energy (thermal nonpower uses as well as power uses) and geothermal power (available only to those projects not accepting the production tax credit [PTC] for geothermal power). In addition, the module reflects the increase in the ITC to 30 percent for solar energy systems installed before January 1, 2017, and the extension of the credit to individual homeowners under EIEA-2008.

PTCs for wind, geothermal, landfill gas, and some types of hydroelectric and biomass-fueled plants also are represented. They provide a credit of up to 2.1 cents per kilowatthour for electricity produced in the first 10 years of plant operation. For *AEO2010*, new wind plants coming on line before January 1, 2013, are eligible to receive the PTC; other eligible plants must be in service before January 1, 2014. As part of ARRA, plants eligible for the PTC may instead elect to receive a 30-percent ITC or an equivalent direct grant. *AEO2010* also accounts for new renewable energy capacity resulting from State renewable portfolio standard (RPS) programs, mandates, and goals, as described in *Assumptions to the Annual Energy Outlook 2010* [*6*].

Oil and Gas Supply Module

The Oil and Gas Supply Module (OGSM) represents domestic crude oil and natural gas supply within an integrated framework that captures the interrelationships among the various sources of supply: onshore, offshore, and Alaska by all production techniques, including natural gas recovery from coalbeds and low-permeability formations of sandstone and shale. The framework analyzes cash flow and profitability to compute investment and drilling for each of the supply sources, based on the prices for crude oil and natural gas, the domestic recoverable resource base, and the state of technology. Oil and natural gas production activities are modeled for 12 supply regions, including 6 onshore, 3 offshore and 3 Alaskan regions.

The *AEO2010* OGSM includes a revised representation of onshore oil and gas supply, the new Onshore Lower 48 Oil and Gas Supply Submodule (OLOGSS), which evaluates the economics of future exploration and development projects for crude oil and natural gas at the play level. Crude oil resources are divided into known plays and undiscovered plays, and include highly fractured continuous zones, such as the Austin chalk and Bakken shale formations. Production potential from advanced secondary recovery techniques (e.g., in-fill drilling, horizontal continuity, and horizontal profile) and enhanced oil recovery (e.g., CO_2 flooding, steam flooding, polymer flooding, and profile modification) are explicitly represented. Natural gas resources are divided into known producing plays, known developing plays, and undiscovered plays in high-permeability carbonate and sandstone, tight gas, shale gas, and coalbed formations.

Domestic crude oil production quantities are used as inputs to the PMM in NEMS for conversion and blending into refined petroleum products. Supply curves for natural gas are used as inputs to the Natural Gas Transmission and Distribution Module for determining natural gas wellhead prices and domestic production.

Natural Gas Transmission and Distribution Module

The Natural Gas Transmission and Distribution Module represents the transmission, distribution, and pricing of natural gas, subject to end-use demand for natural gas, the potential for converting coal to pipeline-quality natural gas, and the availability of domestic natural gas and natural gas traded on the international market. The module tracks the flows of natural gas and determines the associated capacity expansion requirements in an aggregate pipeline network, connecting the domestic and foreign supply regions with 12 U.S. demand regions. The flow of natural gas is determined for both a peak and off-peak period in the year. Key components of pipeline and distributor tariffs are included in separate pricing algorithms. The module also represents foreign sources and destinations of natural gas, including pipeline imports and exports (Canada and Mexico) and liquefied natural gas (LNG) imports and exports. For *AEO2010*, an algorithm was added to project the addition of compressed natural gas retail fueling capability.

Petroleum Market Module

The PMM projects prices of petroleum products, crude oil and product import activity, and domestic refinery operations (including fuel consumption), subject to the demand for petroleum products, the availability and price of imported petroleum, and the domestic production of crude oil, natural gas liquids, and biofuels (ethanol, biodiesel, and biomass-to-liquids [BTL]). The module represents refining activities in the five PADDs, as well as a less detailed representation of refining activities in the rest of the world. It explicitly models the requirements of EISA2007 and CAAA90 and the costs of automotive fuels, such as conventional and reformulated gasoline, and includes the production of biofuels for blending in gasoline and diesel.

The PMM in NEMS represents regulations that limit the sulfur content of all nonroad and locomotive/marine diesel to 15 parts per million (ppm) by mid-2012. The module also reflects the renewable fuels standard (RFS) in EISA2007, which requires the use of 36 billion ethanol-equivalent gallons per year of biofuels by 2022 if achievable, with corn ethanol credits limited to 15 billion gallons per year [*7*]. Demand growth and regulatory changes necessitate capacity expansion for refinery processing units. U.S. end-use prices for petroleum products are based on the marginal costs of production, plus markups representing the costs of product marketing, importing, transportation, and distribution, as well as applicable State and Federal taxes [*8*]. Refinery capacity expansion at existing sites is permitted in each of the five refining regions modeled. Additional detailed information on the PMM can be found in *Assumptions to the Annual Energy Outlook 2010* [*9*].

Fuel ethanol and biodiesel are included in the PMM because they are commonly blended into petroleum products. The module allows ethanol blending into gasoline at 10 percent or less by volume (E10) and up to 85 percent by volume (E85) for use in flex-fuel vehicles. Although blending into gasoline at 15 percent or less by volume (E15) is currently being considered for certification by the EPA as a viable motor fuel, its use in LDVs has not been approved and thus is not modeled for *AEO2010*. In addition, the model reflects the allowable level of non-E85 ethanol blending in California, which has been raised from 5.7 percent to 10 percent in recent regulatory changes that have set a framework for E10 emissions standards starting in year 2010 [*10*].

Ethanol is produced primarily in the Midwest from corn or other starchy crops, and in the future it may be produced from cellulosic material, such as switchgrass, poplar, and crop residues. Biodiesel (diesel-like fuel made in a transesterification process) is produced from seed oil, imported palm oil, animal fats, or yellow grease (primarily, recycled cooking oil). Renewable or “green” diesel is also modeled as a blending component in petroleum diesel. Unlike the more common biodiesel, renewable diesel is made by hydrogenation of vegetable oils or tallow and is completely fungible with petroleum diesel. Imports and limited exports of these biofuels are modeled in the PMM.

Both domestic and imported ethanol count toward the EISA2007 RFS. Domestic ethanol production from three feedstock categories (corn, cellulosic, and advanced) is modeled. Corn-based ethanol plants are numerous (more than 180 are now in operation, with a total operating production capacity of more than 11 billion gallons annually) and are based on a well-known technology that converts starch and sugar into ethanol. Ethanol from cellulosic sources is a new technology, with only a few small pilot plants in operation. Large-scale commercialization of the cellulosic technology is not expected to ramp up quickly enough to meet the cellulosic ethanol mandate in EISA2007.

DOE and the U.S. Department of Agriculture (USDA) have awarded numerous grants to biorefinery projects (over $600 million in 2009 alone), and the USDA has provided a loan guarantee to a small commercial-sized cellulosic biofuel plant scheduled to begin production next year; however, reduced investment during the recent recession is expected to cause significant delays in the startup of large commercial plants, and the delays are reflected in the projections. Imported ethanol can be produced from cane sugar or from bagasse (the cellulosic byproduct of sugar milling). For *AEO2010*, assumptions about ethanol import availability have been reviewed and updated from the previous Reference case, to reflect greater expected availability of ethanol from sugar cane. The sources of ethanol are modeled to compete on an economic basis.

Fuels produced by gasification and Fischer-Tropsch synthesis, or through a pyrolysis process, also are modeled in the PMM, based on their economics relative to competing feedstocks and products. The four processes modeled are CTL, gas-to-liquids (GTL), BTL, and pyrolysis. CTL facilities are likely to be built at locations close to coal supplies and water sources, where liquid products and surplus electricity could also be distributed to nearby demand regions. In addition, a hybrid coal-biomass-to-liquids process was implemented for *AEO2010*. GTL facilities may be built in Alaska, but they would compete with the Alaska Natural Gas Transportation System for available natural gas resources. BTL and pyrolysis facilities are likely to be built where there are large supplies of biomass, such as crop residues and forestry waste. Because the BTL process uses cellulosic feedstocks, it is also modeled as a choice to meet the EISA2007 requirement for cellulosic biofuels.

Coal Market Module

The Coal Market Module (CMM) simulates mining, transportation, and pricing of coal, subject to end-use demand for coal differentiated by heat and sulfur content. U.S. coal production is represented in the CMM by 40 separate supply curves—differentiated by region, mine type, coal rank, and sulfur content. The coal supply curves include a response to capacity utilization of mines, mining capacity, labor productivity, and factor input costs (mining equipment, mining labor, and fuel requirements). Projections of U.S. coal distribution are determined by minimizing the cost of coal supplied, given coal demand by region and sector, environmental restrictions, and accounting for mine-mouth prices, transportation costs, and coal supply contracts. Over the projection horizon, coal transportation costs in the CMM vary in response to changes in the cost of rail investments.

The CMM produces projections of U.S. steam and metallurgical coal exports and imports in the context of world coal trade, determining the pattern of world coal trade flows that minimizes the production and transportation costs of meeting a specified set of regional world coal import demands, subject to constraints on export capacities and trade flows. The international coal market component of the module computes trade in 3 types of coal for 17 export regions and 20 import regions. U.S. coal production and distribution are computed for 14 supply regions and 16 demand regions.

Annual Energy Outlook 2010 cases

Table E1 provides a summary of the cases produced as part of *AEO2010*. For each case, the table gives the name used in this report, a brief description of the major assumptions underlying the projections, the mode in which the case was run in NEMS (either fully integrated, partially integrated, or standalone), and a reference to the pages in the body of the report and in this appendix where the case is discussed. The text sections following Table E1 describe the various cases. The Reference case assumptions for each sector are described in *Assumptions to the Annual Energy Outlook 2010* [*11*]. Regional results and other details of the projections are available at web site www.eia.doe.gov/oiaf/aeo/supplement.

Macroeconomic growth cases

In addition to the *AEO2010* Reference case, the Low Economic Growth and High Economic Growth cases were developed to reflect the uncertainty in projections of economic growth. The alternative cases are intended to show the effects of alternative growth assumptions on energy market projections. The cases are described as follows:

Table E1. Summary of the *AEO2010* cases

Case name	Description	Integration mode	Reference in text	Reference in Appendix E
Reference	Baseline economic growth (2.4 percent per year from 2008 through 2035), world oil price, and technology assumptions. Complete projection tables in Appendix A.	Fully integrated	—	—
Low Economic Growth	Real GDP grows at an average annual rate of 1.8 percent from 2008 to 2035. Other energy market assumptions are the same as in the Reference case. Partial projection tables in Appendix B.	Fully integrated	p. 52	p. 204
High Economic Growth	Real GDP grows at an average annual rate of 3.0 percent from 2008 to 2035. Other energy market assumptions are the same as in the Reference case. Partial projection tables in Appendix B.	Fully integrated	p. 52	p. 204
Low Oil Price	More optimistic assumptions for economic access to non-OPEC resources and for OPEC behavior than in the Reference case. World light, sweet crude oil prices are $51 per barrel in 2035, compared with $133 per barrel in the Reference case (2008 dollars). Other assumptions are the same as in the Reference case. Partial projection tables in Appendix C.	Fully integrated	p. 54	p. 205
High Oil Price	More pessimistic assumptions for economic access to non-OPEC resources and for OPEC behavior than in the Reference case. World light, sweet crude oil prices are about $210 per barrel (2008 dollars) in 2035. Other assumptions are the same as in the Reference case. Partial projection tables in Appendix C.	Fully integrated	p. 54	p. 205
Extended Policies	Begins with the Reference case and selectively extends PTC, ITC, and other energy efficiency tax credit policies with sunset provisions, and promulgates new efficiency standards as they satisfy the consumer-related cost-effectiveness criteria of DOE's Office of Energy Efficiency and Renewable Energy. Introduces new CAFE and tailpipe emissions proposal. Partial projection tables in Appendix D.	Fully integrated	p. 22	p. 210
No Sunset	Begins with the Reference case and extends all energy policies and legislation with sunset provisions, except those requiring additional funding (e.g., loan guarantee programs). Also extends the RFS requirement to 36 billion gallons by 2026 and continues increasing proportional to transport demand thereafter. Partial projection tables in Appendix D.	Fully integrated	p. 22	p. 210
Residential: 2009 Technology	Future equipment purchases based on equipment available in 2009. Existing building shell efficiencies fixed at 2009 levels. Partial projection tables in Appendix D.	With commercial	p. 31	p. 205
Residential: High Technology	Earlier availability, lower costs, and higher efficiencies assumed for more advanced equipment. Building shell efficiencies for new construction meet ENERGY STAR requirements after 2016. Consumers evaluate efficiency investments at a 7-percent real discount rate. Partial projection tables in Appendix D.	With commercial	p. 31	p. 205
Residential: Best Available Technology	Future equipment purchases and new building shells based on most efficient technologies available by fuel. Building shell efficiencies for new construction meet the criteria for most efficient components after 2009. Partial projection tables in Appendix D.	With commercial	p. 31	p. 205

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Table E1. Summary of the *AEO2010* cases (continued)

Case name	Description	Integration mode	Reference in text	Reference in Appendix E
Commercial: 2009 Technology	Future equipment purchases based on equipment available in 2009. Building shell efficiencies fixed at 2009 levels. Partial projection tables in Appendix D.	With residential	p. 31	p. 205
Commercial: High Technology	Earlier availability, lower costs, and higher efficiencies for more advanced equipment. Energy efficiency investments evaluated at a 7-percent real discount rate. Building shell efficiencies for new and existing buildings increase by 17.4 and 7.5 percent, respectively, from 2003 values by 2035. Partial projection tables in Appendix D.	With residential	p. 31	p. 205
Commercial: Best Available Technology	Future equipment purchases based on most efficient technologies available by fuel. Building shell efficiencies for new and existing buildings increase by 20.8 and 9.0 percent, respectively, from 2003 values by 2035. Partial projection tables in Appendix D.	With residential	p. 31	p. 205
Industrial: 2010 Technology	Efficiency of plant and equipment fixed at 2010 levels. Partial projection tables in Appendix D.	Standalone	p. 176	p. 206
Industrial: High Technology	Earlier availability, lower costs, and higher efficiencies for more advanced equipment. Partial projection tables in Appendix D.	Standalone	p. 176	p. 206
Transportation: Low Technology	Advanced technologies are more costly and less efficient than in the Reference case. Partial projection tables in Appendix D.	Standalone	p. 64	p. 206
Transportation: High Technology	Advanced technologies are less costly and more efficient than in the Reference case. Partial projection tables in Appendix D.	Standalone	p. 64	p. 206
Transportation: Reference Case 2019 Phaseout With Base Market Potential	Modified Reference case incorporating lower incremental costs for all classes of heavy-duty natural gas vehicles and tax incentives for natural gas refueling stations and natural gas fuel beginning in 2011 and phased out by 2019. Partial projection tables in Appendix D.	Fully integrated	p. 34	p. 206
Transportation: Reference Case 2027 Phaseout With Expanded Market Potential	Modified Reference case incorporating lower incremental costs for all classes of heavy-duty natural gas vehicles and tax incentives for natural gas refueling stations and natural gas fuel beginning in 2011 and phased out by 2027, with assumed increases in the potential market for all classes of heavy-duty natural gas vehicles. Partial projection tables in Appendix D.	Fully integrated	p. 35	p. 207
Transportation: Low Oil Price Case 2019 Phaseout With Base Market Potential	Modified Low Oil Price case incorporating lower incremental costs for all classes of heavy-duty natural gas vehicles and tax incentives for natural gas refueling stations and natural gas fuel beginning in 2011 and phased out by 2019. Partial projection tables in Appendix D.	Fully integrated	p. 35	p. 207
Transportation: Low Oil Price Case 2027 Phaseout With Expanded Market Potential	Modified Low Oil Price case incorporating lower incremental costs for all classes of heavy-duty natural gas vehicles and tax incentives for natural gas refueling stations and natural gas fuel beginning in 2011 and phased out by 2027, with assumed increases in the potential market for all classes of heavy-duty natural gas vehicles. Partial projection tables in Appendix D.	Fully integrated	p. 35	p. 207
Electricity: Low Fossil Technology Cost	Capital and operating costs for all new fossil-fired generating technologies start 10 percent below the Reference case and decline to 25 percent below the Reference case in 2035. Partial projection tables in Appendix D.	Fully integrated	p. 181	p. 207
Electricity: High Fossil Technology Cost	Costs for new advanced fossil-fired generating technologies do not improve due to learning over time from 2010. Partial projection tables in Appendix D.	Fully integrated	p. 181	p. 207

Table E1. Summary of the *AEO2010* cases (continued)

Case name	Description	Integration mode	Reference in text	Reference in Appendix E
Electricity: Low Nuclear Cost	Capital and operating costs for new nuclear capacity start 10 percent below the Reference case and decline to 25 percent below the Reference case in 2035. Partial projection tables in Appendix D.	Fully integrated	p. 179	p. 207
Electricity: High Nuclear Cost	Costs for new nuclear technology do not improve due to learning from 2010 levels in the Reference case. Partial projection tables in Appendix D.	Fully integrated	p. 179	p. 207
Electricity: Nuclear 60-Year Life	All existing nuclear plants are retired after 60 years of operation. Partial projection tables in Appendix D.	Fully integrated	p. 43	p. 208
Renewable Fuels: Low Renewable Technology Cost	Levelized cost of energy for nonhydropower renewable generating technologies start 10 percent below the Reference case in 2010 and decline to 25 percent below the Reference case in 2035. Partial projection tables in Appendix D.	Fully integrated	p. 69	p. 208
Renewable Fuels: High Renewable Technology Cost	New renewable generating technologies do not improve through learning over time from 2010. Partial projection tables in Appendix D.	Fully integrated	p. 69	p. 208
Oil and Gas: Slow Technology	Improvements in exploration and development costs, production rates, and success rates due to technological advancement are reduced by 50 percent to reflect slower improvement than in the Reference case. Partial projection tables in Appendix D.	Fully integrated	p. 71	p. 208
Oil and Gas: Rapid Technology	Improvements in exploration and development costs, production rates, and success rates due to technological advancement are increased by 50 percent to reflect more rapid improvement than in the Reference case. Partial projection tables in Appendix D.	Fully integrated	p. 71	p. 208
Oil and Gas: No Low-Permeability Gas Drilling	No drilling is permitted in onshore, lower 48 low-permeability natural gas reservoirs after 2009 (i.e., no new tight gas or shale gas drilling). Partial projection tables in Appendix D.	Fully integrated	p. 41	p. 209
Oil and Gas: No Shale Gas Drilling	No drilling is permitted in onshore, lower 48 shale gas reservoirs after 2009 (i.e., no new shale gas drilling). Partial projection tables in Appendix D.	Fully integrated	p. 41	p. 209
Oil and Gas: High Shale Gas Resource	Shale gas resources in the onshore, lower 48 are assumed to be higher than in the Reference case. Partial projection tables in Appendix D.	Fully integrated	p. 41	p. 209
Oil and Gas: High LNG Supply	LNG imports into North America are set exogenously to a factor times the levels projected in the Reference case from 2010 forward. The factor starts at 1.0 in 2010 and increases linearly to 5.0 in 2035. Partial projection tables in Appendix D.	Fully integrated	p. 74	p. 208
Coal: Low Coal Cost	Productivity growth rates for coal mining are higher than in the Reference case, and coal mining wages, mine equipment, and coal transportation rates are lower. Partial projection tables in Appendix D.	Fully integrated	p. 80	p. 209
Coal: High Coal Cost	Productivity growth rates for coal mining are lower than in the Reference case, and coal mining wages, mine equipment, and coal transportation rates are higher. Partial projection tables in Appendix D.	Fully integrated	p. 80	p. 209

Table E1. Summary of the *AEO2010* cases (continued)

Case name	Description	Integration mode	Reference in text	Reference in Appendix E
Integrated Low Technology	Combination of the Residential, Commercial, and Industrial 2010 Technology cases and the Electricity High Fossil Technology Cost, High Renewable Technology Cost, and High Nuclear Cost cases. Partial projection tables in Appendix D.	Fully integrated	p. 32	p. 209
Integrated High Technology	Combination of the Residential, Commercial, Industrial, and Transportation High Technology cases and the Electricity Low Fossil Technology Cost, Low Renewable Technology Cost, and Low Nuclear Cost cases. Partial projection tables in Appendix D.	Fully integrated	p. 32	p. 209
No GHG Concern	No GHG emissions reduction policy is enacted, and market investment decisions are not altered in anticipation of such a policy.	Fully integrated	p. 81	p. 209

- In the Reference case, population grows by 0.9 percent per year, nonfarm employment by 0.8 percent per year, and labor productivity by 2.0 percent per year from 2008 to 2035. Economic output as measured by real GDP increases by 2.4 percent per year from 2008 through 2035, and growth in real disposable income per capita averages 1.8 percent per year.
- The *Low Economic Growth case* assumes lower growth rates for population (0.5 percent per year) and labor productivity (1.5 percent per year), resulting in lower nonfarm employment (0.4 percent per year), higher prices and interest rates, and lower growth in industrial output. In the Low Economic Growth case, economic output as measured by real GDP increases by 1.8 percent per year from 2008 through 2035, and growth in real disposable income per capita averages 1.7 percent per year.
- The *High Economic Growth case* assumes higher growth rates for population (1.3 percent per year) and labor productivity (2.4 percent per year), resulting in higher nonfarm employment (1.2 percent per year). With higher productivity gains and employment growth, inflation and interest rates are lower than in the Reference case, and consequently economic output grows at a higher rate (3.0 percent per year) than in the Reference case (2.4 percent). Disposable income per capita grows by 1.82 percent per year, compared with 1.8 percent in the Reference case.

Oil price cases

The world oil price in *AEO2010* is defined as the average price of light, low-sulfur crude oil delivered in Cushing, Oklahoma, and is similar to the price for light, sweet crude oil traded on the New York Mercantile Exchange. *AEO2010* also includes a projection of the U.S. annual average refiners' acquisition cost of imported crude oil, which is more representative of the average cost of all crude oils used by domestic refiners.

The historical record shows substantial variability in world oil prices, and there is arguably even more uncertainty about future prices in the long term. *AEO2010* considers three price cases (Reference, Low Oil Price, and High Oil Price) to allow an assessment of alternative views on the course of future oil prices. The Low and High Oil Price cases define a wide range of potential price paths, reflecting different assumptions about decisions by OPEC members regarding the preferred rate of oil production and about the future finding and development costs and accessibility of conventional oil resources outside the United States. Because the Low and High Oil Price cases are not fully integrated with a world economic model, the impact of world oil prices on international economies is not accounted for directly.

- In the *Reference case*, real world oil prices rise from a low of $70 per barrel (2008 dollars) in 2010 to $95 per barrel in 2015, then increase more slowly to $133 per barrel in 2035. The Reference case represents EIA's current best judgment regarding exploration and development costs and accessibility of oil resources outside the United States. It also assumes that OPEC producers will choose to maintain their share of the market and will schedule investments in incremental production capacity so that OPEC's conventional oil production will represent about 40 percent of the world's total liquids production.

- In the *Low Oil Price case*, real world oil prices are $51 per barrel (2008 dollars) in 2035, compared with $133 per barrel in the Reference case. The Low Oil Price case assumes that OPEC countries will increase their conventional oil production to obtain a 47-percent share of total world liquids production, and that oil resources outside the United States will be more accessible and/or less costly to produce (as a result of technology advances, more attractive fiscal regimes, or both) than in the Reference case. With these assumptions, conventional oil production outside the United States is higher in the Low Oil Price case than in the Reference case.
- In the *High Oil Price case*, real world oil prices reach about $210 per barrel (2008 dollars) in 2035. The High Oil Price case assumes that OPEC countries will reduce their production from the current rate, sacrificing market share as global liquids production increases, and that oil resources outside the United States will be less accessible and/or more costly to produce than assumed in the Reference case.

Buildings sector cases

In addition to the *AEO2010* Reference case, three standalone technology-focused cases using the Residential and Commercial Demand Modules of NEMS were developed to examine the effects of changes in equipment and building shell efficiencies.

For the residential sector, the three technology-focused cases are as follows:

- The *2009 Technology case* assumes that all future equipment purchases are based only on the range of equipment available in 2009. Existing building shell efficiencies are assumed to be fixed at 2009 levels (no further improvements). For new construction, building shell technology options are constrained to those available in 2009.
- The *High Technology case* assumes earlier availability, lower costs, and higher efficiencies for more advanced equipment [*12*]. For new construction, building shell efficiencies are assumed to meet ENERGY STAR requirements after 2016. Consumers evaluate investments in energy efficiency at a 7-percent real discount rate.
- The *Best Available Technology case* assumes that all future equipment purchases are made from a menu of technologies that includes only the most efficient models available in a particular year for each fuel, regardless of cost. For new construction, building shell efficiencies are assumed to meet the criteria for the most efficient components after 2009.

For the commercial sector, the three technology-focused cases are as follows:

- The *2009 Technology case* assumes that all future equipment purchases are based only on the range of equipment available in 2009. Building shell efficiencies are assumed to be fixed at 2009 levels.
- The *High Technology case* assumes earlier availability, lower costs, and/or higher efficiencies for more advanced equipment than in the Reference case [*13*]. Energy efficiency investments are evaluated at a 7-percent real discount rate. Building shell efficiencies for new and existing buildings in 2035 are assumed to be 17.4 percent and 7.5 percent higher, respectively, than their 2003 levels—a 25-percent improvement relative to the Reference case.
- The *Best Available Technology case* assumes that all future equipment purchases are made from a menu of technologies that includes only the most efficient models available in a particular year for each fuel, regardless of cost. Building shell efficiencies for new and existing buildings in 2035 are assumed to be 20.8 percent and 9.0 percent higher, respectively, than their 2003 values—a 50-percent improvement relative to the Reference case.

The Residential and Commercial Demand Modules of NEMS were also used to complete the High and Low Renewable Technology Cost cases, which are discussed in more detail below (see “Renewable Fuels Cases”). In combination with assumptions for electricity generation from renewable fuels in the electric power sector and industrial sector, these sensitivity cases analyze the impacts of changes in generating technologies that use renewable fuels and in the availability of renewable energy sources. For the Residential and Commercial Demand Modules:

- The *Low Renewable Technology Cost case* assumes greater improvements in residential and commercial PV and wind systems than in the Reference case. The assumptions result in capital cost estimates that are 10 percent below Reference case assumptions in 2010 and decline to at least 25 percent below Reference case costs in 2035.

- The *High Renewable Technology Cost case* assumes that costs and performance levels for residential and commercial PV and wind systems remain constant at 2009 levels through 2035.

Industrial sector cases

In addition to the *AEO2010* Reference case, two standalone cases using the Industrial Demand Module of NEMS were developed to examine the effects of less rapid and more rapid technology change and adoption. Because they are standalone cases, the energy intensity changes discussed in this section exclude the refining industry. (Energy use in the refining industry is estimated as part of the PMM.) The Industrial Demand Module also was used as part of the Integrated Low and High Renewable Technology Cost cases. For the industrial sector:

- The *2010 Technology case* holds the energy efficiency of plant and equipment constant at the 2010 level over the projection period. In this case, delivered energy intensity falls by 0.7 percent annually from 2008 to 2035, as compared with 1.1 percent annually in the Reference case. Changes in aggregate energy intensity may result both from changing equipment and production efficiency and from changing composition of industrial output. Because the level and composition of industrial output are the same in the Reference, 2010 Technology, and High Technology cases, any change in energy intensity in the two technology cases is attributable to efficiency changes.

- The *High Technology case* assumes earlier availability, lower costs, and higher efficiency for more advanced equipment [*14*] and a more rapid rate of improvement in the recovery of biomass byproducts from industrial processes (0.7 percent per year, as compared with 0.4 percent per year in the Reference case). The same assumption is incorporated in the integrated Low Renewable Technology Cost case, which focuses on electricity generation. Although the choice of the 0.7-percent annual rate of improvement in byproduct recovery is an assumption in the High Technology case, it is based on the expectation that there would be higher recovery rates and substantially increased use of CHP in that case. Delivered energy intensity falls by 1.2 percent annually in the High Technology case.

The 2010 Technology case was run with only the Industrial Demand Module, rather than in fully integrated NEMS runs. Consequently, no potential feedback effects from energy market interactions are captured, and energy consumption and production in the refining industry, which are modeled in the PMM, are excluded.

Transportation sector cases

In addition to the *AEO2010* Reference case, two standalone cases using the NEMS Transportation Demand Module were developed to examine the effects of advanced technology costs and efficiency improvement on technology adoption and vehicle fuel economy [*15*]. For the transportation sector:

- In the *Low Technology case*, the characteristics of conventional technologies, advanced technologies, and alternative-fuel LDVs, heavy-duty vehicles, and aircraft reflect more pessimistic assumptions about cost and efficiency improvements achieved over the projection. More pessimistic assumptions for fuel efficiency improvement also are reflected in the rail and shipping sectors.

- In the *High Technology case*, the characteristics of conventional and alternative-fuel LDVs reflect more optimistic assumptions about incremental improvements in fuel economy and costs. In the freight truck sector, the High Technology case assumes more rapid incremental improvement in fuel efficiency for engine and emissions control technologies. More optimistic assumptions for fuel efficiency improvements also are made for the air, rail, and shipping sectors.

The Low Technology and High Technology cases were run with only the Transportation Demand Module rather than as fully integrated NEMS runs. Consequently, no potential macroeconomic feedback related to vehicle costs or travel demand was captured, nor were changes in fuel prices incorporated.

- The *Reference Case 2019 Phaseout With Base Market Potential case* is a modified Reference case that incorporates lower incremental costs for all classes of heavy-duty natural gas vehicles (zero incremental cost relative to their diesel-powered counterparts after accounting for incentives) and tax incentives for natural gas refueling stations ($100,000 per new facility) and for natural gas fuel ($0.50 per gallon of gasoline equivalent) that begin in 2011 and are phased out by 2019.

- The *Reference Case 2027 Phaseout With Expanded Market Potential case* is a modified Reference case with the same added assumptions of lower incremental costs for heavy-duty natural gas vehicles and subsidies for fueling stations and natural gas fuel as in the Reference Case 2019 Phaseout With Base Market Potential case but with the subsidies extended to 2027 before phaseout and, in addition, assumed increases in the potential market for both "fleet" and "non-fleet" natural gas vehicles.

- The *Low Oil Price Case 2019 Phaseout With Base Market Potential case* is a modified Low Oil Price case that incorporates lower incremental costs for all classes of heavy-duty natural gas vehicles (zero incremental cost relative to their diesel-powered counterparts after accounting for incentives) and tax incentives for natural gas refueling stations ($100,000 per new facility) and for natural gas fuel ($0.50 per gallon of gasoline equivalent) that begin in 2011 and are phased out by 2019.
- The *Low Oil Price Case 2027 Phaseout With Expanded Market Potential case* is a modified Low Oil Price case with the same added assumptions of lower incremental costs for heavy-duty natural gas vehicles and subsidies for fueling stations and natural gas fuel as in the Reference Case 2019 Phaseout With Base Market Potential case but with the subsidies extended to 2027 before phaseout and, in addition, assumed increases in the potential market for both "fleet" and "non-fleet" natural gas vehicles.

Electricity sector cases

In addition to the Reference case, several integrated cases with alternative electric power assumptions were developed to analyze uncertainties about the future costs and performance of new generating technologies. Two of the cases examine alternative assumptions for nuclear power technologies, and two examine alternative assumptions for fossil fuel technologies. Reference case values for technology characteristics are determined in consultation with industry and government specialists; however, there is always uncertainty surrounding the major component costs. The electricity cases analyze what could happen if costs of new plants were either higher or lower than assumed in the Reference case. The cases are fully integrated to allow feedback between the potential shifts in fuel consumption and fuel prices.

In addition, for *AEO2010* an alternate retirement case was run for nuclear power plants, to address uncertainties about the operating lives of existing reactors. This scenario is discussed in the Issues in Focus article, "U.S. nuclear power plants: Continued life or replacement after 60?"

Nuclear technology cost cases

- The cost assumptions for the *Low Nuclear Cost case* reflect an approximate 10-percent reduction in capital and operating costs for advanced nuclear technology in 2010, relative to the Reference case, and fall to 25 percent below the Reference case in 2035. The Reference case projects a 35-percent reduction in the capital costs of nuclear power plants from 2010 to 2035; the Low Nuclear Cost case assumes a 45-percent reduction from 2010 to 2035.
- The *High Nuclear Cost case* assumes that capital costs for advanced nuclear technology remain fixed at the 2010 levels assumed in the Reference case. The capital costs still are tied to key commodity price indices, so they change over time; however, no cost improvement from "learning-by-doing" effects is assumed.

Fossil cost technology cases

- In the *Low Fossil Technology Cost case*, capital costs and operating costs for all coal- and natural-gas-fired generating technologies are assumed to start 10 percent lower than Reference case levels and fall to 25 percent lower than Reference case levels in 2035. Because learning in the Reference case reduces costs with manufacturing experience, costs in the Low Fossil Cost case are reduced by 37 to 49 percent between 2010 and 2035, depending on the technology.
- In the *High Fossil Technology Cost case*, capital costs for all coal- and natural-gas-fired generating technologies remain fixed at the 2010 values assumed in the Reference case. Costs still are adjusted year to year by the commodity price index, but no learning-related cost reductions are assumed.

Additional details about annual capital costs, operating and maintenance costs, plant efficiencies, and other factors used in the High and Low Fossil Technology Cost cases will be provided in *Assumptions to the Annual Energy Outlook 2010* [*16*].

Alternative Nuclear Retirement Case

- In the *Nuclear 60-Year Life case*, all existing nuclear plants are assumed to retire after 60 years of operation. In the Reference case, existing plants are assumed to run as long as they continue to be economic, implicitly assuming that a second 20-year license renewal will be obtained for those plants reaching 60 years before 2035. This case was run to analyze the impact of additional nuclear retirements, which could occur if the oldest plants do not receive a second license extension. In this case, 31 gigawatts of nuclear capacity is assumed to be retired by 2035.

Renewable fuels cases

In addition to the *AEO2010* Reference case, two integrated cases with alternative assumptions about renewable fuels were developed to examine the effects of less aggressive and more aggressive improvement in the cost of renewable technologies. The cases are as follows:

- In the *High Renewable Technology Cost case*, capital costs, O&M costs, and performance levels for wind, solar, biomass, and geothermal resources are assumed to remain constant at 2010 levels through 2035. Costs still are tied to key commodity price indexes, but no cost improvement from "learning-by-doing" effects is assumed. Although biomass prices are not changed from the Reference case, this case assumes that dedicated energy crops (also known as "closed-loop" biomass fuel supply) do not become available.
- In the *Low Renewable Technology Cost case*, the levelized costs of energy resources for generating technologies using renewable resources are assumed to start at 10 percent below Reference case levels in 2010 and decline to 25 percent below the Reference case costs for the same resources in 2035. In general, lower costs are represented by reducing the capital costs of new plant construction. Biomass fuel supplies also are assumed to be 25 percent less expensive than in the Reference case for the same resource quantities used in the Reference case. Assumptions for other generating technologies are unchanged from those in the Reference case. In the Low Renewable Technology Cost case, the rate of improvement in recovery of biomass byproducts from industrial processes also is increased.

Oil and gas supply cases

The sensitivity of the projections to changes in the assumed rates of technological progress in oil and natural gas supply and LNG imports is examined in three cases:

- In the *Rapid Technology case*, the parameters representing the effects of technological progress on production rates, exploration and development costs, and success rates for oil and natural gas drilling in the Reference case are improved by 50 percent. Key supply parameters for Canadian natural gas also are modified to simulate the assumed impacts of more rapid natural gas technology penetration on Canadian supply potential. All other parameters in the model are kept at the Reference case values, including technology parameters for other modules, parameters affecting foreign oil supply, and assumptions about imports and exports of LNG and natural gas trade between the United States and Mexico. Specific detail by region and fuel category is provided in *Assumptions to the Annual Energy Outlook 2010* [*17*].
- In the *Slow Technology case*, the parameters representing the effects of technological progress on production rates, exploration and development costs, and success rates for oil and natural gas drilling are 50 percent less optimistic than those in the Reference case. Key Canadian supply parameters also are modified to simulate the assumed impacts of slow natural gas technology penetration on Canadian supply potential. All other parameters in the model are kept at the Reference case values.
- The *High LNG Supply case* exogenously specifies North American LNG import levels for 2010 through 2030 as being equal to a factor times the Reference case levels. The factor starts at 1 in 2010 and increases linearly to 5 in 2035. The intent is to project the potential impact on domestic natural gas markets if LNG imports turn out to be higher than projected in the Reference case.

Three additional cases examine the importance of low-permeability reservoirs on future domestic natural gas supply:

- In the *No Low-Permeability Drilling case*, no new onshore, lower 48 wells are drilled in low permeability natural gas reservoirs (includes shale gas and tight sandstone gas) after 2009. Natural gas production from low-permeability wells drilled before 2010 declines continuously through 2035.
- In the *No Shale Gas Drilling case*, no new onshore, lower 48 shale gas wells are drilled after 2009. Natural gas production from shale gas wells

drilled before 2010 declines continuously through 2035.

- In the *High Shale Gas Resource case*, the resource base for shale gas in the onshore, lower 48 States is assumed to be higher than in the Reference case. Each well can support twice as many shale gas plays as in the Reference case, increasing the resource base from 347 trillion cubic feet in the Reference case to 652 trillion cubic feet in the High Shale Gas Resource case. The estimated recovery from each well is the same as in the Reference case.

Coal market cases

Two alternative coal cost cases examine the impacts on U.S. coal supply, demand, distribution, and prices that result from alternative assumptions about mining productivity, labor costs, mine equipment costs, and coal transportation rates. The alternative productivity and cost assumptions are applied in every year from 2010 through 2035. For the coal cost cases, adjustments to the Reference case assumptions for coal mining productivity are based on variation in the average annual productivity growth of 2.7 percent observed since 2000. Transportation rates are lowered (in the Low Coal Cost case) or raised (in the High Coal Cost case) from Reference case levels to achieve a 25-percent change in rates relative to the Reference case in 2035. The Low and High Coal Cost cases represent fully integrated NEMS runs, with feedback from the macroeconomic activity, international, supply, conversion, and end-use demand modules.

- In the *Low Coal Cost case*, the average annual growth rates for coal mining productivity are higher than those in the Reference case and are applied at the supply curve level. As an example, the average annual growth rate for Wyoming's Southern Powder River Basin supply curve is increased from -0.5 percent in the Reference case for the years 2010 through 2035 to 2.2 percent in the Low Coal Cost case. Coal mining wages, mine equipment costs, and other mine supply costs all are assumed to be about 25 percent lower in 2035 in real terms in the Low Coal Cost case than in the Reference case. Coal transportation rates, excluding the impact of fuel surcharges, are assumed to be 25 percent lower in 2035.
- In the *High Coal Cost case*, the average annual productivity growth rates for coal mining are lower than those in the Reference case and are applied as described in the *Low Coal Cost case*. Coal mining wages, mine equipment costs, and other mine supply costs in 2035 are assumed to be about 30 percent higher than in the Reference case, and coal transportation rates in 2035 are assumed to be 25 percent higher.

Additional details about the productivity, wage, mine equipment cost, and coal transportation rate assumptions for the Reference and alternative Coal Cost cases are provided in Appendix D.

Cross-cutting integrated cases

In addition to the sector-specific cases described above, a series of cross-cutting integrated cases are used in *AEO2010* to analyze specific scenarios with broader sectoral impacts. For example, two integrated technology progress cases combine the assumptions from the other technology progress cases to analyze the broader impacts of more rapid and slower technology improvement rates. In addition, a No GHG Concern case was run that excludes the 3-percent cost-of-capital adjustment for new coal-fired generating capacity and for CTL plants without CCS. In the Reference case, this adjustment is included to simulate the reluctance of regulators and the investment community to invest in GHG-intensive technologies, given uncertainty about the possible enactment of limits on GHG emissions.

Integrated technology cases

The *Integrated Low Technology case* combines the assumptions from the residential, commercial, and industrial 2010 Technology cases and the electricity High Fossil Technology Cost, High Renewable Technology Cost, and High Nuclear Cost cases. The *Integrated High Technology case* combines the assumptions from the residential, commercial, industrial, and transportation High Technology cases and the electricity High Fossil Technology Cost, Low Renewable Technology Cost, and Low Nuclear Cost cases.

Extended Policies case

In addition to the *AEO2010* Reference case, an additional case was run assuming that selected policies with sunset provisions (such as the PTC, ITC, and tax credits for energy-efficient equipment in the buildings sector) will be extended indefinitely rather than allowed to sunset as the law currently prescribes. Further, updates to Federal appliance efficiency standards were assumed to occur at intervals provided by law and at levels determined by the consumer impact test in DOE testing procedures or Federal Energy Management Program (FEMP) purchasing guidelines. Finally, proposed rules by NHTSA and the EPA for national tailpipe CO_2-equivalent emissions and fuel economy standards for LDVs, including both passenger cars and light-duty trucks, were harmonized and incorporated in this case.

In the electricity market, tax credits for renewable generation capacity that are available currently but are scheduled to expire are instead assumed to be extended indefinitely—including the PTC of 2.1 cents per kilowatthour or, as appropriate, the 30-percent ITC available for wind, geothermal, biomass, hydroelectric, and landfill gas resources. For solar capacity, a 30-percent ITC that is scheduled to revert to a 10-percent tax credit in 2016 is, instead, assumed to be extended indefinitely at 30 percent.

In the buildings sector, tax credits for the purchase of energy-efficient equipment, including PV and new houses, are extended indefinitely, as opposed to ending in 2010 or 2016 as prescribed by current law. The business ITCs for commercial-sector generation technologies and geothermal heat pumps are extended indefinitely, as opposed to expiring in 2016, and the business ITC for solar systems is kept at 30 percent instead of reverting to 10 percent. In addition, updates to appliance standards are assumed to occur as prescribed by the timeline in DOE's multiyear plan. The efficiency levels chosen for the updated standard were based on the technology menu in the *AEO2010* Reference case and whether or not the efficiency level passed the consumer impact test prescribed in DOE's standards-setting process. The efficiency levels chosen for updated commercial equipment standards are based on the technology menu from the *AEO2010* Reference case and FEMP-designated purchasing specifications for Federal agencies.

NHTSA and the EPA have proposed rules for coordinated national CO_2-equivalent tailpipe emissions and fuel economy standards for LDVs, including both passenger cars and light-duty trucks. The harmonized fuel economy standards begin in model year (MY) 2012 and increase in stringency to MY 2016, based on NHTSA's recently proposed CAFE standards. NHTSA has estimated the impact of the new CAFE standards and has projected that the proposed fleet-wide standards for LDVs will increase fuel economy from 27.3 miles per gallon in MY 2011 to 34.1 miles per gallon in MY 2016, based on projected sales of vehicles by type and footprint. Separate mathematical functions representing the CAFE standards are established for passenger cars and light trucks, reflecting their different design capabilities. As required by EISA2007, the fuel economy standards increase to 35 miles per gallon by 2020. The Extended Policies case assumes that these standards are further increased so that the minimum fuel economy standard achieved for LDVs increases to 45.6 miles per gallon in 2035.

No Sunset case

Assumptions for extensions of the renewable energy tax credit and the buildings tax credit are the same as in the Extended Policies case described above. No updates to appliance or CAFE standards are assumed. This case also extends the RFS target to that originally set by law (36 billion ethanol-equivalent gallons) and assumes that the target is achieved by 2026 instead of 2022; after 2026, the RFS requirement continues to increase so that it remains at the same percentage of total transport fuel demand as achieved in 2026. Biofuel tax credits and the import tariffs also are extended.

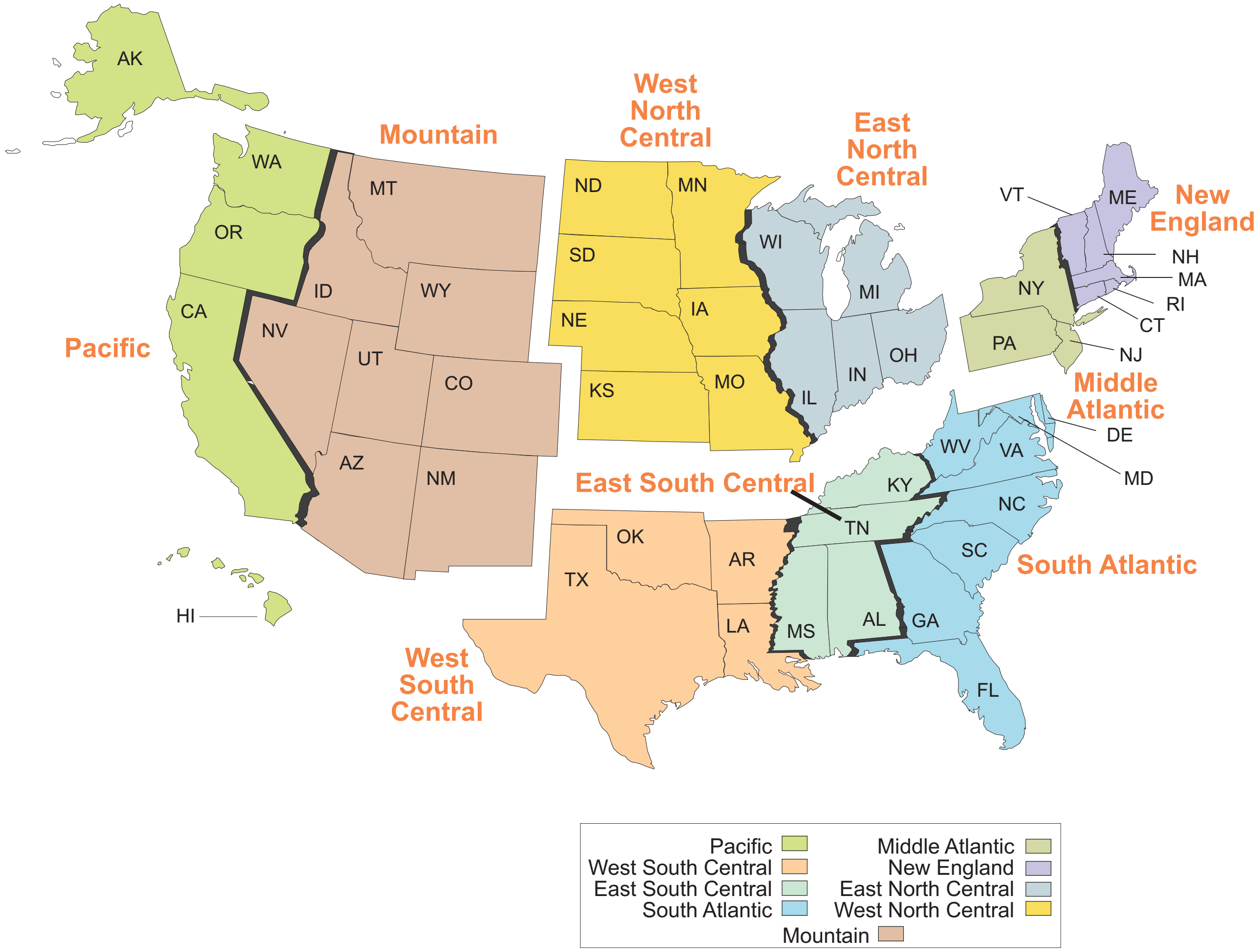
Endnotes

1. U.S. Energy Information Administration, *The National Energy Modeling System: An Overview 2009*, DOE/EIA-0581(2009) (Washington, DC, March 2009), web site http://www.eia.doe.gov/oiaf/aeo/overview/index.html.
2. U.S. Energy Information Administration, *Annual Energy Review 2008*, DOE/EIA-0384(2008) (Washington, DC, June 2009), web site www.eia.doe.gov/emeu/aer/contents.html.
3. U.S. Energy Information Administration, *Emissions of Greenhouse Gases in the United States 2007*, DOE/EIA-0573(2008) (Washington, DC, December 2009), web site www.eia.doe.gov/oiaf/1605/ggrpt/index.html.
4. U.S. Energy Information Administration, *Short-Term Energy Outlook*, web site www.eia.doe.gov/emeu/steo/pub/contents.html. Portions of the preliminary information were also used to initialize the NEMS Petroleum Market Module projection.
5. Jet Information Services, Inc., *World Jet Inventory Year-End 2006* (Utica, NY, March 2007); and personal communication from Stuart Miller (Jet Information Services).
6. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2010*, DOE/EIA-0554(2010) (Washington, DC, March 2010), web site www.eia.doe.gov/oiaf/aeo/assumption.
7. Corn ethanol production may exceed 15 billion gallons if it is economical to do so without the RFS credit.
8. For gasoline blended with ethanol, the tax credit of 51 cents (nominal) per gallon of ethanol is assumed to be available for 2008; however, it is reduced to 45 cents starting in 2009 (the year after annual U.S. ethanol consumption surpasses 7.5 billion gallons), as mandated by the Food, Conservation, and Energy Act of 2008 (the Farm Bill), and it is set to expire after 2010. In addition, modeling updates include the Farm Bill's mandated extension of the ethanol import tariff, at 54 cents per gallon, to December 31, 2010. Finally, again in accordance with the Farm Bill, a new cellulosic ethanol producer's tax credit of $1.01 per gallon, valid through 2012, is implemented in the model; however, it is reduced by the amount of the blender's tax credit. Thus, in 2009 and 2010, the cellulosic ethanol producer's tax credit is modeled as $1.01 - $0.45 = $0.56 per gallon, and in 2011 and 2012 it is set at $1.01 per gallon. (Note: Taxes discussed in this footnote are in nominal dollars.)
9. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2010*, DOE/EIA-0554(2010) (Washington, DC, March 2010), web site www.eia.doe.gov/oiaf/aeo/assumption.
10. California Environmental Protection Agency, Air Resources Board, "Phase 3 California Reformulated Gasoline Regulations," web site www.arb.ca.gov/regact/2007/carfg07/carfg07.htm.
11. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2010*, DOE/EIA-0554(2010) (Washington, DC, March 2010), web site www.eia.doe.gov/oiaf/aeo/assumption.
12. High technology assumptions for the residential sector are based on Energy Information Administration, *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case Second Edition (Revised)* (Navigant Consulting, Inc., September 2007), and *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case: Residential and Commercial Lighting, Commercial Refrigeration, and Commercial Ventilation Technologies* (Navigant Consulting, Inc., September 2008).
13. High technology assumptions for the commercial sector are based on Energy Information Administration, *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case Second Edition (Revised)* (Navigant Consulting, Inc., September 2007), and *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Advanced Case: Residential and Commercial Lighting, Commercial Refrigeration, and Commercial Ventilation Technologies* (Navigant Consulting, Inc., September 2008).
14. These assumptions are based in part on Energy Information Administration, *Industrial Technology and Data Analysis Supporting the NEMS Industrial Model* (FOCIS Associates, October 2005).
15. U.S. Energy Information Administration, *Documentation of Technologies Included in the NEMS Fuel Economy Model for Passenger Cars and Light Trucks* (Energy and Environmental Analysis, September 2003).
16. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2010*, DOE/EIA-0554(2010) (Washington, DC, March 2010), web site www.eia.doe.gov/oiaf/aeo/assumption.
17. U.S. Energy Information Administration, *Assumptions to the Annual Energy Outlook 2010*, DOE/EIA-0554(2010) (Washington, DC, March 2010), web site www.eia.doe.gov/oiaf/aeo/assumption.

Appendix F

Regional Maps

Figure F1. United States Census Divisions



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

Regional Maps

Figure F1. United States Census Divisions (cont.)

Division 1
New England

Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont

Division 2
Middle Atlantic

New Jersey
New York
Pennsylvania

Division 3
East North Central

Illinois
Indiana
Michigan
Ohio
Wisconsin

Division 4
West North Central

Iowa
Kansas
Minnesota
Missouri
Nebraska
North Dakota
South Dakota

Division 5
South Atlantic

Delaware
District of Columbia
Florida
Georgia
Maryland
North Carolina
South Carolina
Virginia
West Virginia

Division 6
East South Central

Alabama
Kentucky
Mississippi
Tennessee

Division 7
West South Central

Arkansas
Louisiana
Oklahoma
Texas

Division 8
Mountain

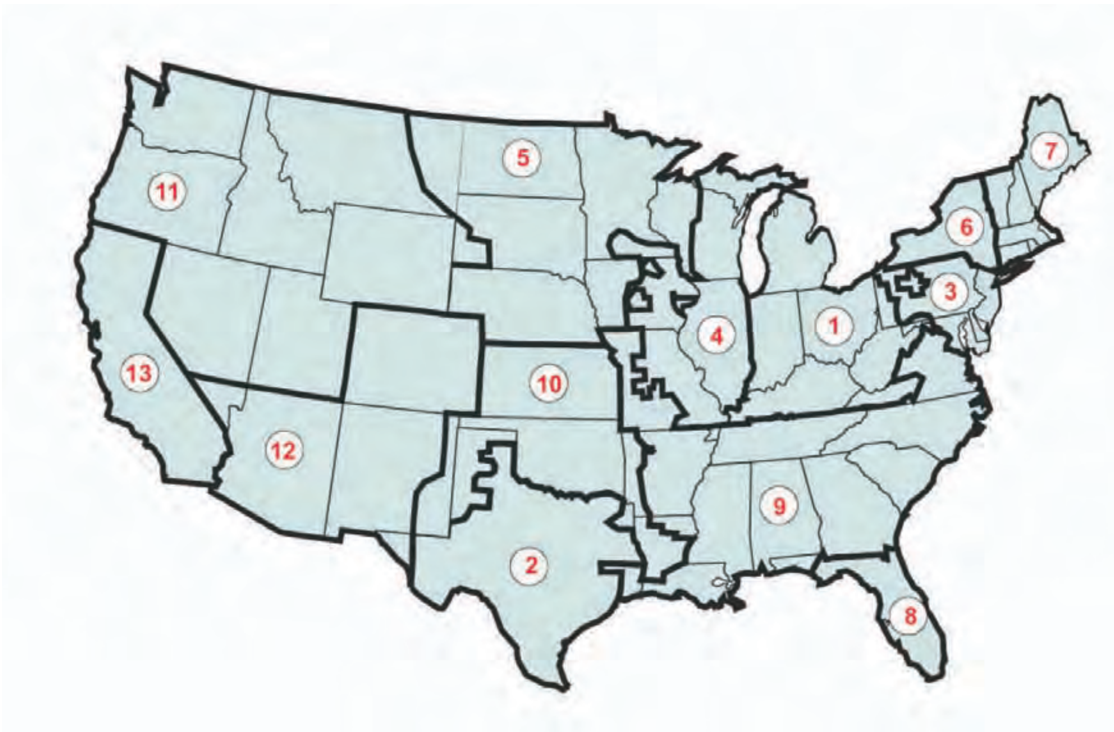
Arizona
Colorado
Idaho
Montana
Nevada
New Mexico
Utah
Wyoming

Division 9
Pacific

Alaska
California
Hawaii
Oregon
Washington

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

Figure F2. Electricity Market Module Regions

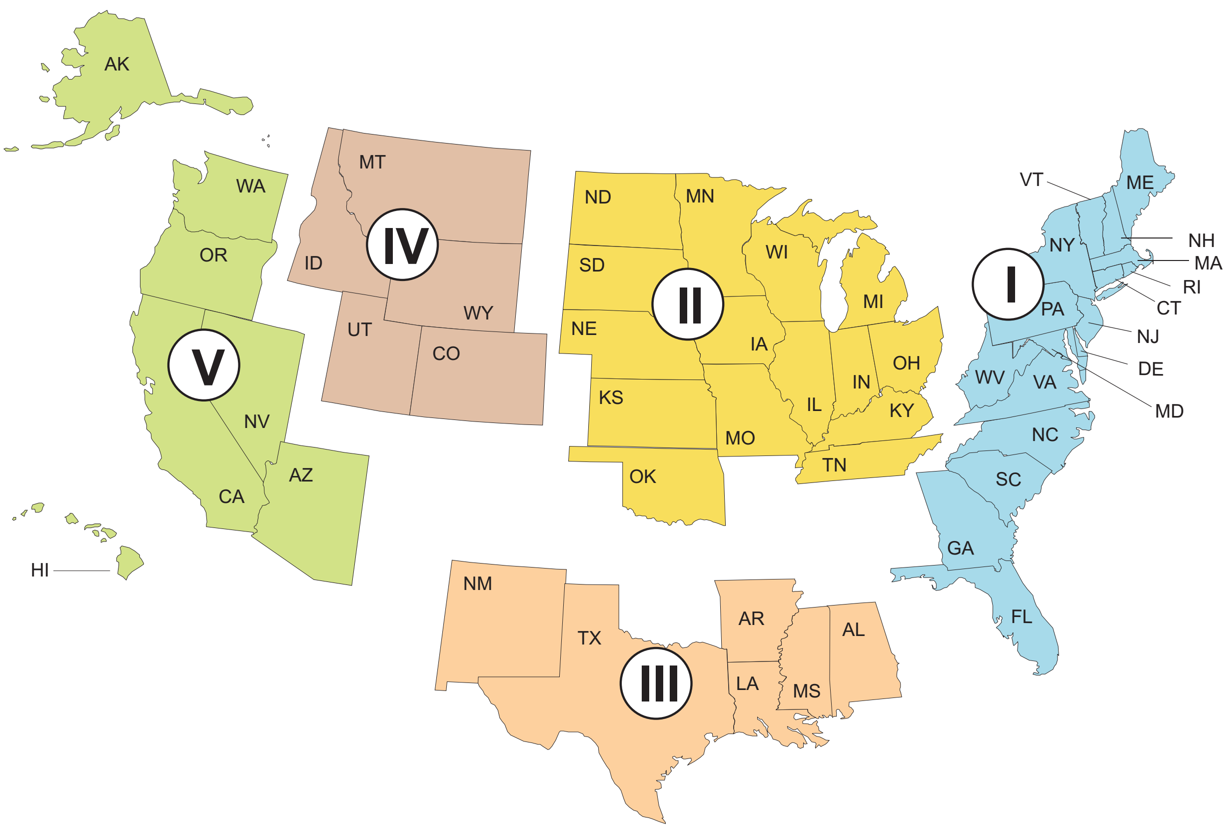


1 East Central Area Reliability Coordination Agreement (ECAR)
2 Electric Reliability Council of Texas (ERCOT)
3 Mid-Atlantic Area Council (MAAC)
4 Mid-America Interconnected Network (MAIN)
5Mid-Continent Area Power Pool (MAPP)
6 New York (NY)
7. New England (NE)
8 Florida Reliability Coordinating Council (FL)
9 Southeastern Electric Reliability Council (SERC)
10 Southwest Power Pool (SPP)
11 Northwest Power Pool (NPP)
12 Rocky Mountain Power Area, Arizona, New
New Mexico, and Southern Nevada (RA)
13 California (CA)

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

Regional Maps

Figure F3. Petroleum Administration for Defense Districts



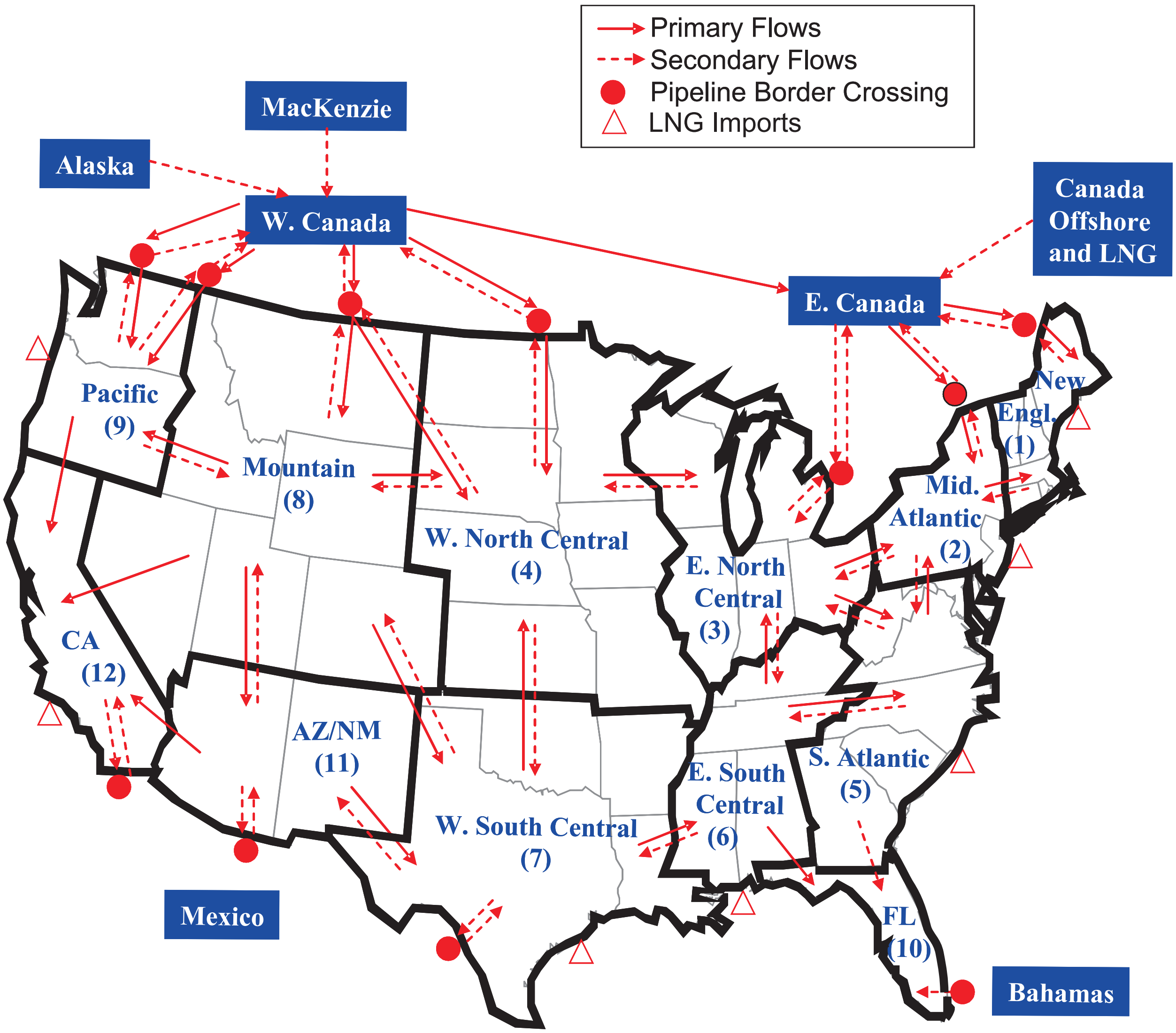
PAD District I - East Coast
PAD District II - Midwest
PAD District III - Gulf Coast
PAD District IV - Rocky Mountain
PAD District V - West Coast

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

Figure F4. Oil and Gas Supply Model Regions

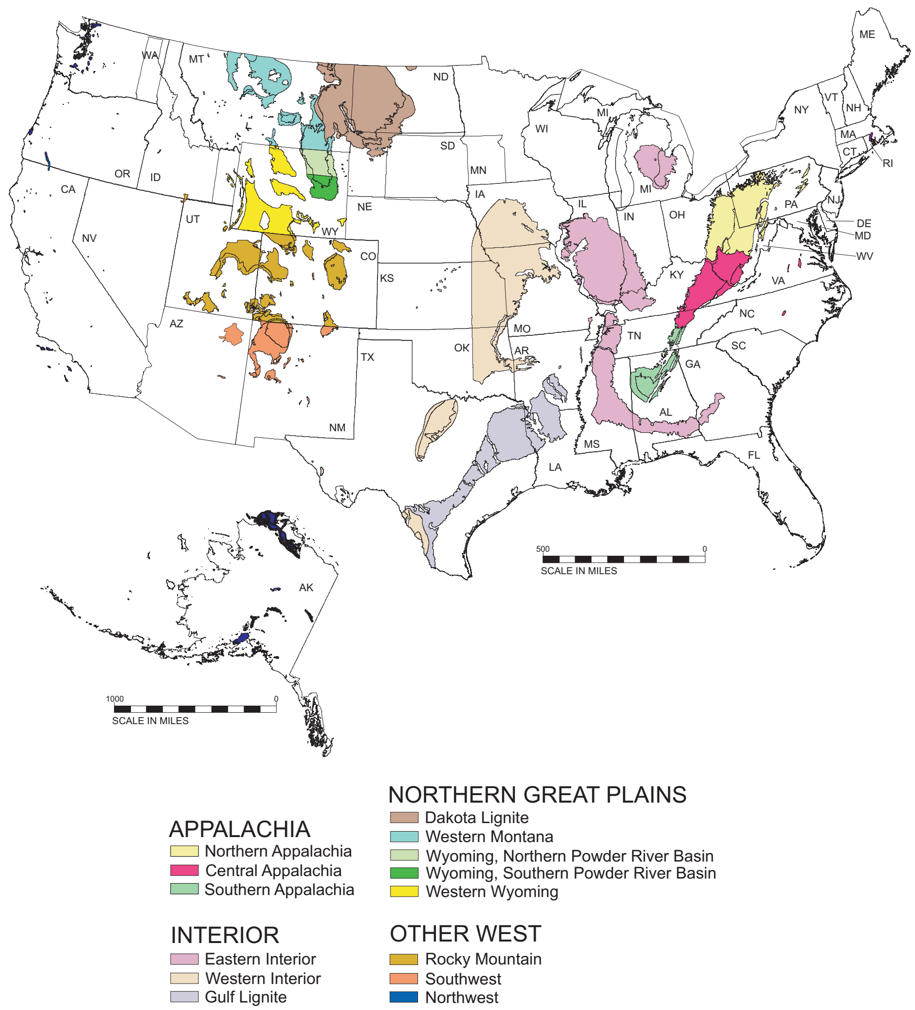
Source: U.S. Energy Information Administration, Office of Integrated Analysis and Forecasting.

Figure F5. Natural Gas Transmission and Distribution Model Regions



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

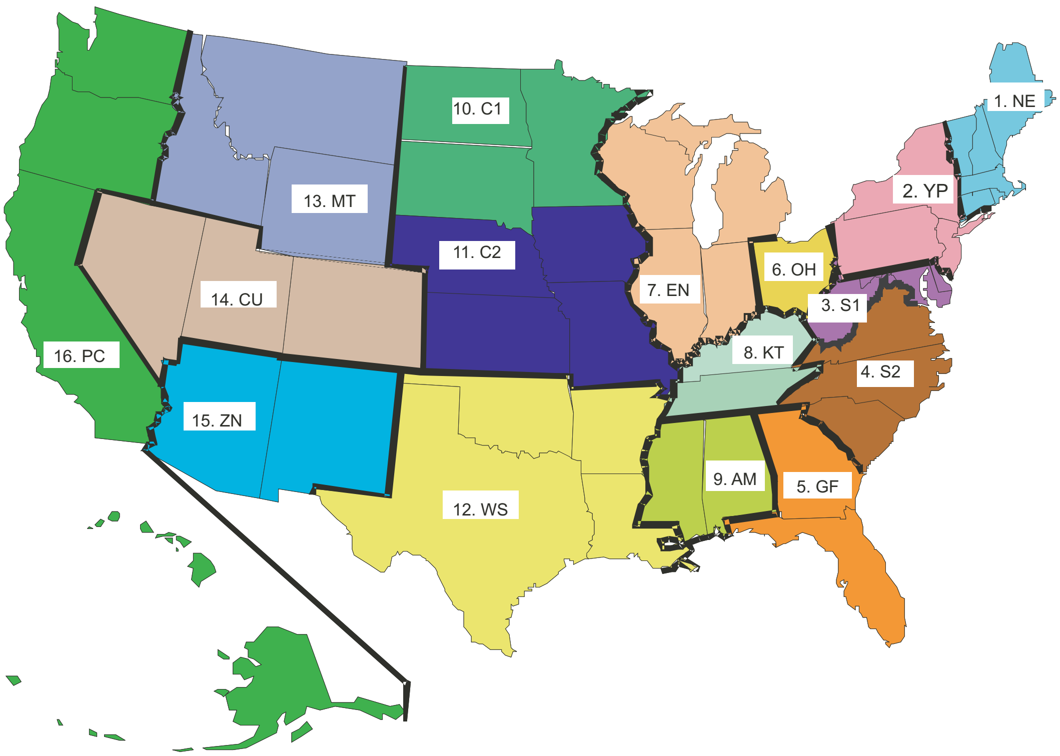
Figure F6. Coal Supply Regions



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

Regional Maps

Figure F7. Coal Demand Regions



Region Code	Region Content
1. NE	CT,MA,ME,NH,RI,VT
2. YP	NY,PA,NJ
3. S1	WV,MD,DC,DE
4. S2	VA,NC,SC
5. GF	GA,FL
6. OH	OH
7. EN	IN,IL,MI,WI
8. KT	KY,TN

Region Code	Region Content
9. AM	AL,MS
10. C1	MN,ND,SD
11. C2	IA,NE,MO,KS
12. WS	TX,LA,OK,AR
13. MT	MT,WY,ID
14. CU	CO,UT,NV
15. ZN	AZ,NM
16. PC	AK,HI,WA,OR,CA

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

Conversion Factors

Table G1. Heat Rates

Fuel	Units	Approximate Heat Content
Coal[1]		
Production	million Btu per short ton	20.213
Consumption	million Btu per short ton	19.989
Coke Plants	million Btu per short ton	26.280
Industrial	million Btu per short ton	22.361
Residential and Commercial	million Btu per short ton	21.359
Electric Power Sector	million Btu per short ton	19.726
Imports	million Btu per short ton	25.116
Exports	million Btu per short ton	25.393
Coal Coke	million Btu per short ton	24.800
Crude Oil		
Production	million Btu per barrel	5.800
Imports[1]	million Btu per barrel	5.990
Liquids		
Consumption[1]	million Btu per barrel	5.301
Motor Gasoline[1]	million Btu per barrel	5.128
Jet Fuel	million Btu per barrel	5.670
Distillate Fuel Oil[1]	million Btu per barrel	5.775
Diesel Fuel[1]	million Btu per barrel	5.766
Residual Fuel Oil	million Btu per barrel	6.287
Liquefied Petroleum Gases[1]	million Btu per barrel	3.600
Kerosene	million Btu per barrel	5.670
Petrochemical Feedstocks[1]	million Btu per barrel	5.565
Unfinished Oils	million Btu per barrel	6.118
Imports[1]	million Btu per barrel	5.542
Exports[1]	million Btu per barrel	5.840
Ethanol	million Btu per barrel	3.539
Biodiesel	million Btu per barrel	5.376
Natural Gas Plant Liquids		
Production[1]	million Btu per barrel	3.948
Natural Gas[1]		
Production, Dry	Btu per cubic foot	1,028
Consumption	Btu per cubic foot	1,028
End-Use Sectors	Btu per cubic foot	1,029
Electric Power Sector	Btu per cubic foot	1,027
Imports	Btu per cubic foot	1,025
Exports	Btu per cubic foot	1,009
Electricity Consumption	Btu per kilowatthour	3,412

[1]Conversion factor varies from year to year. The value shown is for 2008.
Btu = British thermal unit.
Sources: Energy Information Administration (EIA), *Annual Energy Review 2008*, DOE/EIA-0384(2008) (Washington, DC, June 2009), and EIA, AEO2010 National Energy Modeling System run AEO2010R.D111809A.