DOE/EIA-0581(96)
Distribution Category UC-950

The National Energy Modeling System: An Overview

March 1996

Energy Information Administration
Office of Integrated Analysis and Forecasting
U.S. Department of Energy
Washington, DC 20585

PREFACE

The National Energy Modeling System: An Overview (*Overview*) provides a summary description of the National Energy Modeling System (NEMS), which was used to generate the forecasts of energy production, demand, imports, and prices through the year 2015 for the *Annual Energy Outlook 1996* (*AEO96*), (DOE/EIA-0383(96)), released in January 1996. The *AEO96* presents national forecasts of energy markets for five cases—a reference case and four additional cases that assume higher and lower economic growth and higher and lower world oil prices than in the reference case. The *Overview* presents a brief description of the methodology and scope of each of the component modules of NEMS. The model documentation reports listed in the appendix of this document provide further details.

The *Overview* was prepared by the Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting under the direction of Mary J. Hutzler (mhutzler@eia.doe.gov, 202/586-2222), Director of the Office of Integrated Analysis and Forecasting; Arthur T. Andersen (aanderse@eia.doe.gov, 202/586-1441), Director of the Energy Demand and Integration Division; Scott Sitzer (ssitzer@eia.doe.gov, 202/586-2308), Director of the Energy Supply and Conversion Division; and Andy S. Kydes (akydes@eia.doe.gov, 202/586-2222), Senior Modeling Analyst. Detailed questions concerning NEMS may be addressed to the following analysts:

AEO96	Susan H. Shaw (sshaw@eia.doe.gov, 202/586-4838)
Integrating Module	Daniel H. Skelly (dskelly@eia.doe.gov, 202/586-1722)
International Energy Module	G. Daniel Butler (gbutler@eia.doe.gov, 202/586-9503)
Macroeconomic Activity Module	Kay A. Smith (ksmith@eia.doe.gov, 202/586-1455)
Oil and Gas Supply Module	Dana Van Wagener (dwagener@eia.doe.gov, 202/586-4725)
Natural Gas Transmission and Distribution Module	James Diemer (jdiemer@eia.doe.gov, 202/586-6126)
Coal Market Module	Richard Newcombe (rnewcomb@eia.doe.gov, 202/586-2415)
Renewable Fuels Module	Perry Lindstrom (plindstr@eia.doe.gov, 202/586-0934)
Electricity Market Module	Jeffrey Jones (jjones@eia.doe.gov, 202/586-2038)
Petroleum Market Module	Bruce Bawks (bbawks@eia.doe.gov, 202/586-6579)
Residential Demand Module	John Cymbalsky (jcymbals@eia.doe.gov, 202/586-4815)
Commercial Demand Module	Erin Boedecker (eboedeck@eia.doe.gov, 202/586-4791)
Industrial Demand Module	T. Crawford Honeycutt (choneycu@eia.doe.gov, 202/586-1420)
Transportation Demand Module	David Chien (dchien@eia.doe.gov, 202/586-3994)

The *AEO96* is available on the EIA CD-ROM and the EIA Home Page on the Internet. The displays on the Home Page include text, forecast tables, and graphics. To download the report or tables, go to the EIA FTP site (ftp://ftp.eia.doe.gov). Assumptions underlying the projections in the *AEO96* are also available on the CD-ROM and the Home Page. Model documentation reports are available on the CD-ROM. The forecast tables published in the *AEO96* and additional tables of regional projections and other underlying details of the reference case are available on diskettes, the CD-ROM, and the Home Page in worksheet form. The forecast tables published in the *AEO96* are also available via modem on EIA's Electronic Publication (EPUB) System (202/586-2557). To obtain diskettes, contact the Office of Scientific and Technical Information, by telephone at 615/576-8401 or by mail at P.O. Box 62, Oak Ridge, TN 37831.

For ordering information, please contact EIA's National Energy Information Center.

National Energy Information Center, EI-231
Energy Information Administration
Forrestal Building, Room 1F-048
Washington, DC 20585
202/586-8800
TTY: For people who are deaf or hard of hearing: 202/586-1181
9 a.m. to 5 p.m., eastern time, M-F
E-mail: *infoctr@eia.doe.gov*
World Wide Web Site: *http://www.eia.doe.gov*
Gopher Site: *gopher://gopher.eia.doe.gov*
FTP Site: *ftp://ftp.eia.doe.gov*

CONTENTS

CONTENTS

Page

Figures

INTRODUCTION

The National Energy Modeling System (NEMS) is a computer-based, energy-economy modeling system of U.S. energy markets for the midterm period of 1990 through 2015. NEMS projects the production, imports, conversion, consumption, and prices of energy, subject to assumptions on macroeconomic and financial factors, world energy markets, resource availability and costs, behavioral and technological choice criteria, cost and performance characteristics of energy technologies, and demographics. NEMS was designed and implemented by the Energy Information Administration (EIA) of the U.S. Department of Energy (DOE).

The National Energy Modeling System: An Overview presents an overview of the structure and methodology of NEMS and each of its components. This chapter provides a description of the design and objectives of the system, followed by a chapter on the overall modeling structure and solution algorithm. The remainder of the report summarizes the methodology and scope of the component modules of NEMS. The model descriptions are intended for readers familiar with terminology from economics, operations research, and energy modeling. More detailed model documentation reports for all the NEMS modules are also available from EIA (Appendix, "Bibliography").

Purpose of NEMS

NEMS is used by EIA to project the energy, economic, environmental, and security impacts on the United States of alternative energy policies and of different assumptions about energy markets. Projections are made for each year from the present through 2015. This time period is one in which technology, demographics, and economic conditions are sufficiently understood in order to represent energy markets with a reasonable degree of confidence.

Baseline forecasts are developed with NEMS and published annually in the *Annual Energy Outlook*. In accordance with the requirement that EIA remain policy-neutral, the *Annual Energy Outlook* projections assume that all existing legislation, regulations, and policies remain unchanged. Analyses are also prepared in response to requests for special studies by the U.S. Congress, the DOE Office of Policy, and others. The first version of NEMS, completed in December 1993, was used to develop the forecasts presented in the *Annual Energy Outlook 1994*.[1] This report describes the version of NEMS used for the *Annual Energy Outlook 1996* (AEO96),[2] which is the first *Annual Energy Outlook* to extend the projections through 2015.

The forecasts produced by NEMS are not considered to be absolute predictions of the future. They are contingent on the key assumptions made about U.S. energy systems. Contingencies include, for example, the estimated size of the economically recoverable resource base of fossil fuels, changes in world energy supply and demand, the rate at which new energy technologies are developed and the rate and extent of their penetration into commercial markets, and existing or prospective government actions or policies.

NEMS was built to support energy policy analysis and to serve as a resource for the development and analysis of the impacts of alternative energy policies on key U.S. markets and economic growth. NEMS provides a consistent framework for representing the complex interactions of the U.S. energy system and its response to a wide variety of alternative assumptions and policies or policy initiatives.

NEMS can be used to analyze the effects of existing and proposed government laws and regulations related to energy production and use; the potential impacts of new and advanced energy production, conversion, and consumption technologies; the impacts of increased use of renewable energy sources; the potential savings from demand-side management and increased efficiency of energy use; and the changes in emission levels that are likely to result from such policies as the Clean Air Act Amendments of 1990 and regulations on the use of alternative or reformulated fuels. Other examples of energy topics that can be, or have been, addressed by NEMS include the following:

- Impacts of energy tax policies on the U.S. economy and energy system
- Responses of the energy and economic systems to changes in world oil market conditions as a result of changing levels of foreign production and demand in the developing countries
- Impacts of new technologies on consumption and production patterns and emissions
- Effects of specific policies, such as mandatory appliance efficiency and building shell standards, on energy consumption

[1]Energy Information Administration, *Annual Energy Outlook 1994*, DOE/EIA-0383(94) (Washington, DC, January 1994).
[2]Energy Information Administration, *Annual Energy Outlook 1996*, DOE/EIA-0383(96) (Washington, DC, January 1996).

- Impacts of fuel-use restrictions (for example, required use of oxygenated and reformulated gasoline or mandated use of alternative-fueled vehicles) on emissions, energy supply and prices, and economic growth
- Changes in natural gas prices and pipeline and import capacity in response to Federal and State regulatory initiatives
- Impacts on the production of crude oil and natural gas resulting from improvements in exploration and production technologies.

In addition to producing the analyses in the *Annual Energy Outlook* from 1994 through 1996, NEMS has been used for a variety of DOE studies over the last 2 years. Studies conducted for the Office of Policy and the Office of Energy Efficiency and Renewable Energy include analyses of the impacts of lower electricity prices due to industry restructuring, more rapid efficiency improvements of consumption technologies due to research and development, and lower capital costs of renewable generation technologies. NEMS also supported the Department's Domestic Natural Gas and Oil Initiative and provided the baseline results for 1995 National Energy Policy Plan. In a study conducted for the Office of Naval Petroleum Reserves, the petroleum market module—refinery module—of NEMS was modified to represent Los Angeles and San Francisco area refineries. The module was then used to determine the value to refiners of crude oil from the Naval Petroleum Reserve, exploiting the module's capability to analyze crude oil and product specifications, product slates, and refining units.

Representations of Energy Market Interactions

NEMS was designed to represent the important interactions of supply and demand in U.S. energy markets. In the United States, energy markets are driven primarily by the fundamental economic interactions of supply and demand. Government regulations and policies can exert considerable influence, but the majority of decisions affecting fuel prices and consumption patterns, resource allocation, and energy technologies are made by private individuals or companies attempting to optimize their own economic interests. NEMS represents the market behavior of the producers and consumers of energy at a level of detail that is useful for analyzing the implications of technological improvements and policy initiatives. The representation of energy markets in NEMS focuses on four important interrelationships:

- Interactions among the energy fuel supply, conversion, and consumption sectors
- Interactions between the domestic energy system and the domestic economy
- Interactions between the U.S. energy system and world energy markets
- Interactions between current production and consumption decisions and expectations about the future.

Energy Supply/Conversion/Demand Interactions

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

Domestic Energy System/Economy Interactions

The general level of economic activity, represented by gross domestic product, has traditionally been used as a key explanatory variable or driver for projections of energy consumption at the sectoral and regional levels. In turn, energy prices and other energy system activities influence economic growth and activity. NEMS captures this feedback between the domestic economy and the energy system. Thus, changes in energy prices affect the key macroeconomic variables—such as gross domestic product, disposable personal income, industrial output, housing starts, employment, and interest rates—that drive energy consumption and capacity expansion decisions.

Domestic/World Energy Market Interactions

World oil prices play a key role in domestic energy supply and demand decisionmaking, and oil price assumptions are the typical starting point for energy system projections. The level of oil production and consumption in the U.S. energy system also has a significant influence on world oil markets and prices. In NEMS, an international energy module represents world oil production and demand, as well as the interactions between the domestic and world oil markets, and this module calculates the average world crude oil price and the supply of specific crude oils and petroleum products. As a result, domestic and world oil market projections are internally consistent. Imports and exports of natural gas, electricity, and coal—which are less influenced by volatile world conditions—are represented in the individual fuel supply modules.

Economic Decisionmaking Over Time

The production and consumption of energy products today are influenced by past investment decisions to develop energy resources and acquire energy-using capital stock. Similarly, the production and consumption of energy in a future time period will be influenced by decisions made today and in the past. Current investment decisions depend on expectations about future markets. For example, expectations of rising energy prices in the future increase the likelihood of current decisions to invest in developing alternative energy sources. A variety of assumptions about planning horizons, the formation of expectations about the future, and the role of those expectations in economic decisionmaking are applied within the individual NEMS modules.

External Availability

In accordance with EIA requirements, NEMS is fully documented and archived. NEMS is executed on three EIA RS/6000 workstations. The archive tape will enable a user with similar equipment to run the system, and the model has been installed at the National Renewable Energy Laboratory and other locations. The modules of NEMS as used for the *Annual Energy Outlook 1995*[3] are available for the personal computer with a Windows-based user interface. Limited updates of the modules for *AEO96* are also available by contacting EIA.

[3]Energy Information Administration, *Annual Energy Outlook 1995*, DOE/EIA-0383(95) (Washington, DC, January 1995).

OVERVIEW OF NEMS

NEMS represents domestic energy markets by explicitly representing the economic decisionmaking involved in the production, conversion, and consumption of energy products. For example, the penetration of a new or advanced technology for electricity generation is projected only if the technology is deemed to be economically viable at projected energy prices as generators assess the cost-minimizing mix of fuels and equipment costs over the life of the equipment.

Since energy costs and availability and energy-consuming characteristics can vary widely across regions, considerable regional detail is included. Other details of production and consumption categories are represented to facilitate policy analysis and ensure the validity of the results. A summary of the detail provided in NEMS is shown below.

Energy Activity	Categories	Regions
Supply		
Oil	Conventional Enhanced	Six lower 48 onshore regions Three lower 48 offshore regions Three Alaska regions
Natural gas	Conventional shallow Conventional deep Coalbed methane Devonian shale Tight sands	Six lower 48 onshore regions Three lower 48 offshore regions Three Alaska regions
Natural gas transmission and distribution	Firm vs. interruptible vs. competitive Peak vs. offpeak	Twelve regions Nine pipeline border points Five liquefied natural gas terminals
Coal	Four sulfur categories Four thermal categories Underground and surface mining types	Sixteen supply regions Twenty-three demand regions Sixteen export regions Twenty import regions
Renewables	Hydroelectric, wind-electric, geothermal-electric, solar-electric, municipal solid waste, ethanol, biomass-electric	Fifteen electricity supply regions Five Petroleum Administration for Defense Districts Nine Census divisions
Conversion		
Electricity	Utilities Independent and small power producers	Fifteen electricity supply regions Nine Census divisions for demand
Refining	Five crude oil categories Seven product categories	Five Petroleum Administration for Defense Districts
Demand		
Residential	Eight end-use services Three housing types	Nine Census divisions
Commercial	Nine end-use services Eleven building types	Nine Census divisions
Transportation	Six car sizes Six truck sizes Ten vintages	Nine Census divisions
Industrial	Thirty-two industries Eight energy-intensive industries Cogeneration	Four Census regions, shared to nine Census divisions

OVERVIEW OF THE STRUCTURE OF NEMS

Major Assumptions

Each module of NEMS embodies many assumptions and data to characterize the future production, conversion, or consumption of energy in the United States. Any one or more of several hundred variables are specified to create a new case. Two major classes of assumptions characterizing a case are assumptions concerning economic growth in the United States and assumptions about foreign oil supply and demand and their influence on world oil prices.

The five comprehensive, integrated cases in the *AEO96* are defined by setting assumptions that lead to a high, mid, or low economic growth rate for the domestic economy and to a high, mid, or low world oil price path. The reference case uses the mid-range assumptions for both the economic growth rate and the world oil price. Higher and lower economic growth and higher and lower world oil prices define the other four cases. The primary determinants for different economic growth rates are the growth rates of the labor force and productivity, while different assumptions on oil production levels by the Organization of Petroleum Exporting Countries (OPEC) and the former Soviet Union and Eastern Europe lead to different levels of world oil prices.

In addition to the five baseline cases, the *AEO96* includes 20 other cases that explore the impacts of varying key assumptions in the individual components of NEMS. Most of these cases involve changes in the assumptions that impact the penetration of new or improved technologies, which is a major uncertainty in formulating projections of future energy markets. These cases exploit the modular structure of NEMS by running only a portion of the entire modeling system, in most cases only one component module, in order to focus on the first-order impacts of the changes in the assumptions.

NEMS Modular Structure

Overall, NEMS represents a modeling system that simulates the behavior of energy markets and their interactions with the U.S. economy. The model achieves a supply/demand balance in the end-use demand regions, defined as the nine Census divisions (Figure 1), by solving for the prices of each energy product that will balance the quantities producers are willing to supply with the quantities consumers wish to consume. The system reflects market economics, industry structure, and energy policies and regulations that influence market behavior.

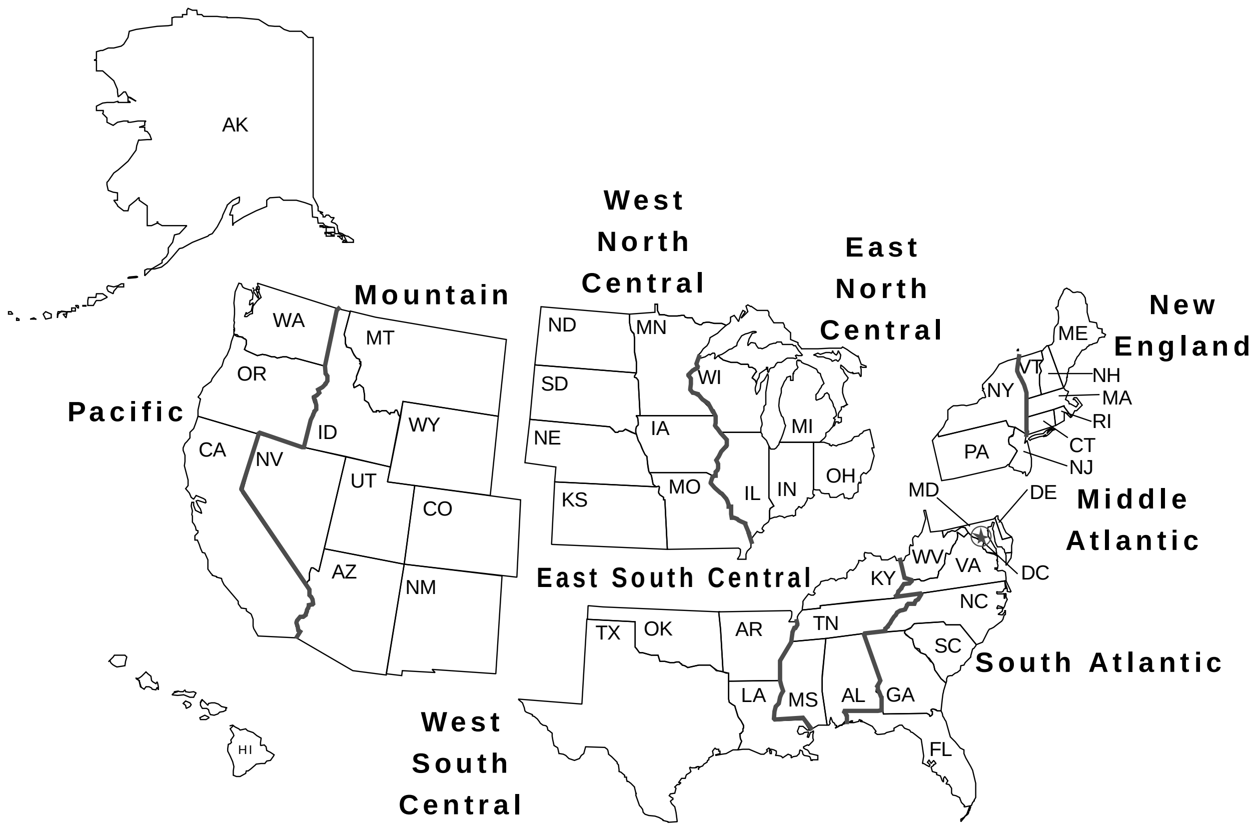
NEMS consists of four supply modules (oil and gas, natural gas transmission and distribution, coal, and renewable fuels); two conversion modules (electricity and petroleum refineries); four end-use demand modules (residential, commercial, transportation, and industrial); one module to simulate energy/economy interactions (macroeconomic activity); one module to simulate world oil markets (international energy activity); and one module that provides the mechanism to achieve a general market equilibrium among all the other modules (integrating module). Figure 2 depicts the high-level structure of NEMS.

Because energy markets are heterogeneous, a single methodology does not adequately represent all supply, conversion, and end-use demand sectors. The modularity of the NEMS design provides the flexibility for each component of the U.S. energy system to use the methodology and coverage that is most appropriate. Furthermore, modularity provides the capability to execute the modules individually or in collections of modules, which facilitates the development and analysis of the separate component modules. The interactions among these modules are controlled by the integrating module.

The NEMS Global Data Structure is used to coordinate and communicate the flow of information among the modules. These data are passed through common interfaces via the integrating module. The Global Data Structure includes energy market prices and consumption; macroeconomic variables; energy production, transportation, and conversion information; and centralized model control variables, parameters, and assumptions. The Global Data Structure excludes variables that are defined locally within the modules and are not communicated to other modules.

A key subset of the variables in the Global Data Structure are the end-use prices and quantities of fuels which are used to equilibrate the NEMS energy balance in the convergence algorithm. These delivered prices of energy and the quantities demanded are defined by product, region, and sector. The delivered prices of fuel encompass all the activities necessary to produce, import, and transport fuels to the end user. The regions for the price and quantity variables in the Global Data Structure are the nine Census divisions. The four Census regions (shown in Figure 1 by breaks between State groups) and nine Census divisions are a common, mainstream level of regionality widely used by EIA and other organizations for data collection and analysis.

Figure 1. Census Divisions



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

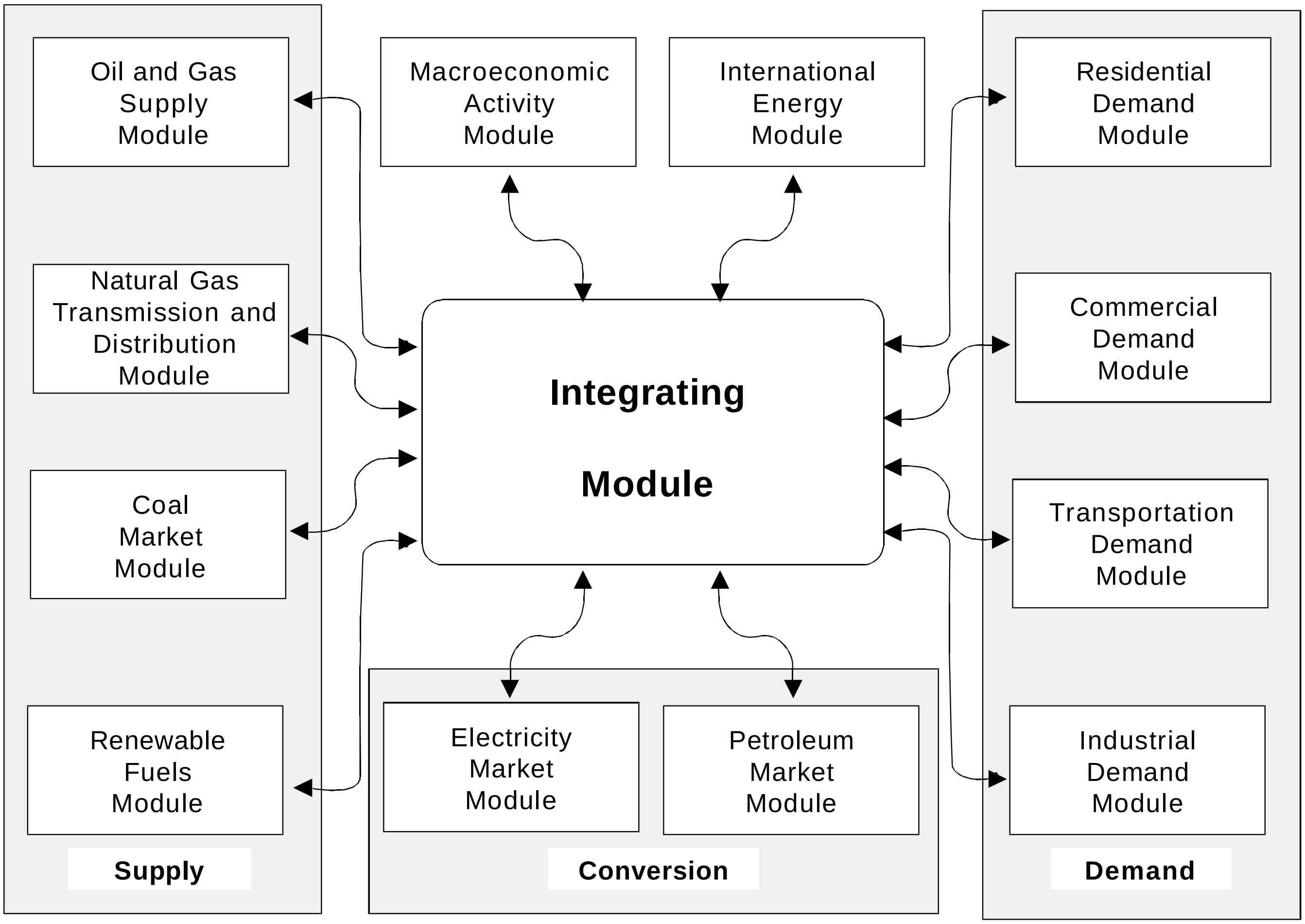
Division 8
Mountain

Arizona
Colorado
Idaho
Montana
Nevada
New Mexico
Utah
Wyoming

Division 9
Pacific

Alaska
California
Hawaii
Oregon
Washington

Figure 2. National Energy Modeling System



Integrating Module

The NEMS integrating module controls the entire NEMS solution process as it iterates to determine a general market equilibrium across all the NEMS modules. It has the following functions:

- Manages the NEMS Global Data Structure
- Executes all or any of the user-selected modules in an iterative convergence algorithm
- Checks for convergence, while reporting variables that remain out of convergence
- Implements price relaxation between iterations to accelerate convergence
- Updates expected values of the key NEMS variables
- Computes estimates of carbon emissions.

The integrating module executes the demand, conversion, and supply modules iteratively until it achieves an economic equilibrium of supply and demand in all the consuming and producing sectors. Each module is called in sequence and solved, assuming that all other variables in the energy markets are fixed. The modules are called iteratively until the end-use prices and quantities remain constant within a specified tolerance—a condition defined as convergence. Equilibration is achieved annually through the midterm period through 2015 for each of the nine Census divisions.

In addition, the macroeconomic and international modules are executed iteratively to incorporate the feedback on the economy and international markets from changes in the domestic energy markets. The convergence tests check the stability of a set of key macroeconomic and international trade variables in response to interaction with the domestic energy system.

The NEMS algorithm executes the system of modules until convergence is reached. The solution procedure for one iteration involves the execution of all the component modules, as well as the updating of expectation variables (related to foresight assumptions) for use in the next iteration. The system is executed sequentially for each year in the forecast period. During each iteration within a year, each of the analytical modules is executed in turn, with intervening convergence checks that isolate specific modules that are not converging. A separate convergence check is made for prices and quantities, consisting of a comparison of the absolute values of the percentage changes to an assumed tolerance. To avoid unnecessary iterations for changes in insignificant values, the quantity convergence check is omitted for quantities less than a user-specified minimum level. The order of execution of the modules may affect the rate of convergence but will generally not prevent convergence to an equilibrium solution or significantly alter the results. An optional relaxation routine can be executed to dampen swings in solution values between iterations. With this option, the current iteration values are reset partway between solution values from the current and previous iterations.

Because of the modular structure of NEMS and the iterative solution algorithm, any single module or subset of modules can be executed independently. Modules not executed are bypassed in the calling sequence, and the values they would calculate and provide to the other modules are held fixed at the values in the Global Data Structure, which would be the solution values from a previous run of NEMS. This flexibility is an aid to independent development, debugging, and analysis.

In addition, the integrating module computes the carbon emissions due to the combustion of energy. These computations are centralized in a routine that also permits the imposition of carbon taxes for potential policy analyses.

INTERNATIONAL ENERGY MODULE

The international energy module (IEM) calculates the average price of imported crude oil and provides supply curves for 5 grades of crude oil and 10 petroleum products for import into the United States. In addition, it performs the following functions:

- Calculates the change in world oil price in response to shifts in U.S. petroleum supply and demand
- Provides petroleum product supply curves with a representation of foreign product supply levels and associated costs for imports of petroleum products into the United States
- Calculates shifts in supply curves for petroleum product imports as a result of variations in demand for U.S. product imports, world oil price, and economic conditions
- Provides supply curves for U.S. imports of the oxygenates methyl tertiary butyl ether (MTBE) and methanol.

Three separate submodules of the IEM (Figure 3) carry out these functions. The world oil market submodule is an expanded version of the Oil Market Simulation Model that was used for world oil price forecasts before NEMS was developed. The world oil market submodule forecasts international crude oil market conditions, including price and supply availability, and the effects of U.S. demand on the world market. The petroleum products supply submodule produces supply curves for petroleum products imported into the United States. These supply curves reflect conditions in the international market, including refinery capacity, transportation costs, and the effects of U.S. demand on world markets. Finally, the oxygenates supply submodule produces supply curves for U.S. imports of MTBE and methanol.

The petroleum products supply and oxygenates supply submodules use the world oil price generated by the world oil market submodule. Otherwise, the three submodules of the IEM are independent, providing feedback through the rest of NEMS during system iteration. A summary of important IEM inputs and outputs is given below.

World Oil Market Submodule

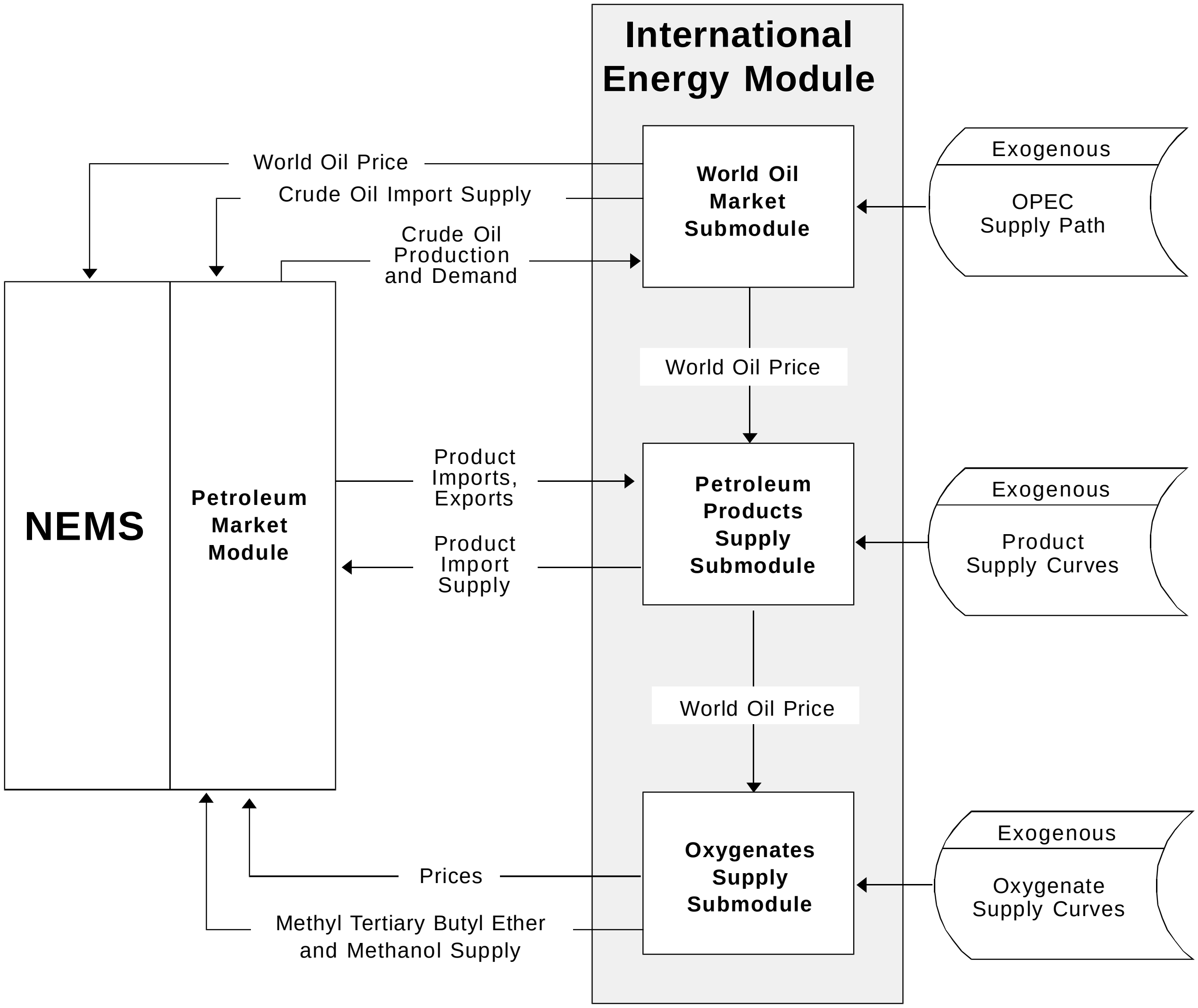
EIA's modeling of the near- to mid-term world oil market depends on two key assumptions: (1) oil is the marginal fuel and (2) the Organization of Petroleum Exporting Countries (OPEC) produces the marginal supply at prices that tend to inhibit the market penetration of new technologies, particularly technologies producing synthetic fuels. Under these assumptions, world oil prices are computed to provide a balance of supply and demand for crude oil in the international market as a function of OPEC production decisions, supply of non-OPEC oil, and international demand for oil, which depends upon worldwide economic growth. Under the assumption that oil is the marginal fuel, competition between oil and other fuels can be ignored, because switching between fuels is assumed to be too small to affect the world oil price. The second assumption means that the price of oil is not allowed to go so high as to induce the market penetration of new technology that would reduce the demand for oil sufficiently to produce substantial downward pressure on its price. U.S. import supply curves for several qualities of crude oils are generated as a function of the world oil price, production sources, transportation rates, and the utilization and/or expansion of worldwide refining capacity. World crude oil sales are mapped into the five classes used in the petroleum market module (see page 38).

Petroleum Products Supply Submodule

The petroleum products supply submodule consists of a set of import product supply curves to all five Petroleum Administration for Defense Districts (PADDs) for each petroleum product that may be imported in NEMS. The petroleum market module uses the supply curves to determine the quantity and price to be imported. The supply curves were developed from a separate large-scale model of international refining and transportation that is used as an auxiliary to NEMS. Supply curves for 10 products are provided: traditional gasoline (including aviation), reformulated gasoline, No. 2 heating oil, low-sulfur distillate oil, high- and low-sulfur residual oil, jet fuel (including naphtha jet), liquefied petroleum gas, petrochemical feedstocks, and other.

Important IEM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
World oil price Crude oil import supply Product import supply Methyl tertiary butyl ether and methanol supply Other oxygenate prices	U.S. crude oil production and demand U.S. product imports and exports	OPEC production path Reference non-U.S. oil supply and demand Product and oxygenate supply curves

Figure 3. International Energy Module Structure



Oxygenates Supply Submodule

Supply curves for MTBE and methanol are developed from data on pricing practices for current production capacity and assumptions about pricing for new production capacity that is under construction or expected to be constructed in the future. The curves are used in the same ways as the petroleum product supply curves just described. The oxygenates supply submodule calculates prices for oxygenate imports, based on import quantities estimated by the petroleum market module. The petroleum market module then recalculates the quantity of imports and iterates with the oxygenates supply submodule until convergence is obtained.

Because of the potential expansion of the U.S. ethanol industry and the lack of commercial markets for other oxygenates, it is assumed that ethanol, ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), and tertiary butyl alcohol (TBA) are all supplied from domestic sources. Therefore, the IEM does not provide import supply curves for these oxygenates.

MACROECONOMIC ACTIVITY MODULE

The macroeconomic activity module (MAM) provides forecasts of economic variables to the energy modules within NEMS and forecasts the impacts on the aggregate economy of changes in energy market conditions. The MAM consists of two submodules (the national and interindustry submodules) and a subroutine (the regional subroutine), which are run in sequence. The national submodule provides forecasts of a wide range of economic variables at the national level. In particular, it provides variables that drive other parts of NEMS, including interest rates, final demands for goods and services, and disposable income. The interindustry submodule calculates the industrial output needed to satisfy the final demands from the national submodule. The levels of industrial output are used by the industrial and transportation demand modules in NEMS to calculate energy consumption in those sectors. Finally, the regional subroutine of the MAM takes national variable values from the national and interindustry submodules and transforms them into appropriate regional values. The overall interrelationships are shown in Figure 4.

The sequence of interactions in the MAM begins with the energy supply and demand modules of NEMS, which determine the reaction of energy prices. These energy price effects are passed to the national submodule, and the economy is projected to react to the altered energy price paths. The altered macroeconomic final demands are in turn passed to the interindustry submodule, which calculates their effect on interindustry activity. The altered interindustry projections are then passed back to the other NEMS modules, and the system iterates until convergence is achieved.

MAM outputs include measures of macroeconomic performance and manufacturing and nonmanufacturing sector production activities. Depending on the concept, these measures are provided nationally or at the geographic level of the nine Census divisions (see Figure 1). A summary of important MAM inputs and outputs is given below.

National Submodule

The national submodule of MAM is a response surface representation of the Data Resources, Inc. (DRI) U.S. Quarterly Model. (A *response surface* representation is a set of equations embodying important inputs and outputs of a larger, detailed model. The coefficients of the equations are estimated via statistical/econometric methods, based on "pseudodata" derived from repeated runs of the larger model being represented.) The response surface representation simulates the reaction to changing energy prices of the larger version of the DRI U.S. Quarterly Model. The growth potential of the economy is essentially grounded in the growth of the factors of production—labor, capital, and energy—and the aggregate productivity of these factors. The user can select three different macroeconomic growth cases before executing the MAM, and MAM will estimate how the economy changes in response to changing energy prices. These growth cases are initially derived from simulations of the DRI U.S. Quarterly Model and are used as the starting point to examine energy/economic impacts.

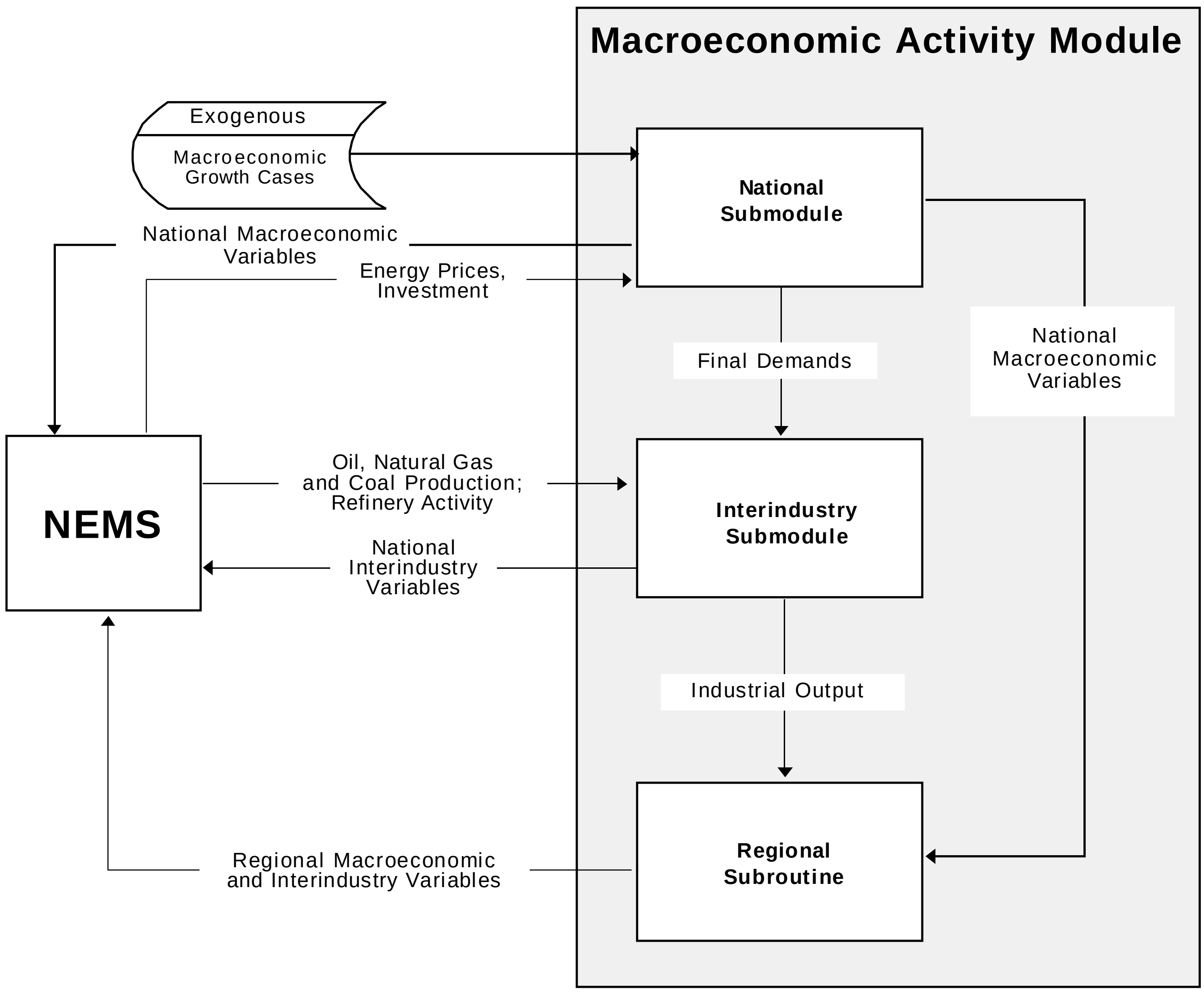
Interindustry Submodule

The interindustry submodule provides industrial output projections to the regional MAM subroutine and the energy modules. It also calculates interindustry impacts associated with changes in national economic activity resulting from energy price changes. A response surface version of the DRI Input-Output Model for the Personal Computer constitutes the core interindustry segment of this submodule, which is fully linked to other NEMS components.

The interindustry submodule calculates deviations from a given baseline interindustry projection whenever macroeconomic final demands change. Because of the top-down structure of input-output modeling, the interindustry and national submodules do not iterate directly with each other. However, through their joint effect on the projections of the energy supply and

Important MAM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Gross domestic product Other economic activity measures Price indices and deflators Production rates for manufacturing Production rates for nonmanufacturing Interest rates	Wholesale and retail prices for electricity Wholesale and retail prices and production rates for oil, gas, and coal Level of oil refinery output Investment	Macroeconomic growth cases

Figure 4. Macroeconomic Activity Module Structure



demand modules, which in turn alter the macroeconomic outlook, changes in interindustry projections affect the results of the national submodule.

Regional Subroutine

The initial implementation of the regional subroutine is a set of equations that share national economic and industrial output data to specific regions. The sharing equations are derived from the Regional Macroeconomic Model developed by DRI. The regional subroutine disaggregates national economic variables such as disposable income, industrial production, and consumer prices into appropriate regional values.

Oil and Gas Supply Module

The oil and gas supply module (OGSM) consists of a series of process submodules that project the availability of:

- Domestic crude oil production and dry natural gas wellhead production from onshore, offshore, and Alaskan reservoirs
- Imported pipeline-quality gas from Mexico and Canada
- Imported liquefied natural gas.

The OGSM regions are shown in Figure 5.

The driving assumption of the OGSM is that domestic oil and gas exploration and development are undertaken if the discounted present value of the recovered resources at least covers the present value of taxes and the cost of capital, exploration, development, and production, subject to a budget constraint. In contrast, international gas trade is determined in part by scenario-dependent, noneconomic factors. Crude oil is transported to refineries (which are simulated in the petroleum market module) for conversion and blending into refined petroleum products.

The individual submodules of the oil and gas supply module are solved independently, with feedbacks achieved through NEMS solution iterations (Figure 6). Important OGSM inputs and outputs are shown below.

Lower 48 Supply Submodule

The lower 48 supply submodule projects oil and gas production by conventional recovery methods in onshore and offshore regions and unconventional gas recovery in onshore regions. Unconventional gas is defined as gas produced from nonconventional geologic formations, as opposed to conventional (sandstones) and carbonate rock formations. The three nonconventional geologic formations considered are low-permeability or tight sandstones, Devonian shale, and coalbed methane. Enhanced oil recovery from onshore regions is handled separately. The lower 48 submodule actually consists of three separate submodules: onshore lower 48 conventional oil and gas supply, offshore oil and gas supply, and unconventional gas recovery supply.

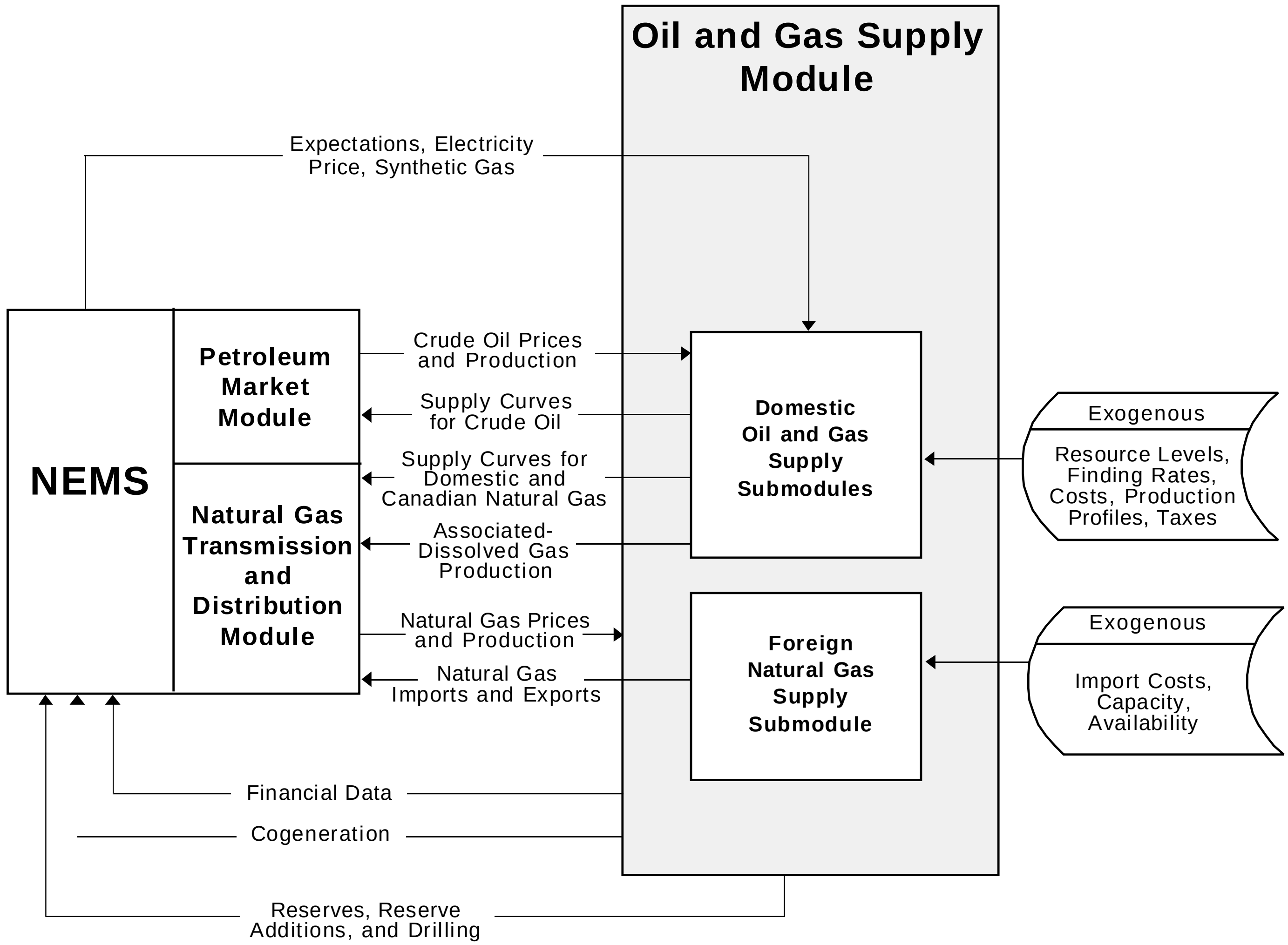
The lower 48 submodule accounts for drilling, reserves estimates, and production capacity—computed independently (for the most part) for each region (6 onshore and 3 offshore) by well class (exploratory and developmental) and fuel category (conventional oil, conventional shallow gas, conventional deep gas, and unconventional gas):

- First, the prospective costs of a representative drilling project (for a given fuel category and well class within a given region) are computed. Costs are a function of national levels of drilling activity and the effects of technological progress.
- Second, the present value of the discounted cash flows (DCF) associated with the representative project is computed. These cash flows include both the capital and operating costs of the project (including royalties and taxes) and the revenues derived from a declining well production profile (computed after taking into account the progressive effects of resource depletion and valued at constant real prices as of the year of initial valuation).
- Third, drilling expenditure levels are calculated as a function of projected profitability as measured by the projected DCF levels for each project.
- Fourth, the drilling expenditure levels are divided by drilling costs to determine the level of drilling in each period for each fuel and well class in each region.
- Fifth, regional finding rate equations are used to forecast new field discoveries from new field wildcats, new pools and extensions from other exploratory drilling, and reserve revisions from development drilling.

Important OGSM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Domestic and Canadian supply curve parameters Oil and gas financial data Pipeline gas and liquefied natural gas imports (excluding Canada) and exports Cogeneration from oil and gas production Reserves and reserve additions Annual drilling levels Associated-dissolved gas production	Oil and gas production by fuel type Oil, gas, and electricity prices Synthetic gas production Canadian natural gas imports and production	Resource levels Initial finding rate parameters and costs Production profiles Tax parameters Import capacity

Figure 5. Oil and Gas Supply Module Regions

Figure 6. Oil and Gas Supply Module Structure



- Sixth, production is determined within the market equilibration of the natural gas transmission and distribution module and the petroleum market module on the basis of fuel demands, reserves (including new reserve additions), previous productive capacity, and flow from new wells.

Alaska Oil and Gas Submodule

This submodule projects the crude oil and natural gas produced in Alaska. The Alaska oil and gas submodule is divided into three sections: new field discoveries, development projects, and producing fields. Oil and gas transportation costs to lower 48 facilities are used in conjunction with the relevant market price of oil or gas to calculate the estimated net price received at the wellhead, sometimes called the "netback price." A discounted cash flow method is used to determine the economic viability of each project at the netback price.

Alaskan oil and gas supplies are modeled on the basis of discrete projects, in contrast to the onshore lower 48 conventional oil and gas supplies, which are modeled on an aggregate level. The continuation of the exploration and development of multiyear projects, as well as the discovery of a new field, is dependent on its profitability. Production is determined on the basis of assumed drilling schedules and production profiles for new fields and developmental projects, historical production patterns, and announced plans for currently producing fields.

Enhanced Oil Recovery Submodule

A field-based engineering submodule with hybrid exogenous (off-line) and endogenous (on-line) components is used to simulate the exploration and development of enhanced oil recovery (EOR) resources—a process that differs significantly from conventional oil and gas exploration and development:

- The exogenous EOR component creates tabular outputs that are subsequently used as inputs by the endogenous EOR component, which runs interactively within the OGSM. Inputs to the exogenous EOR component include assumed future natural gas prices and rates of technological progress, as well as resource levels, reserves, producing wells, production profiles, oil gravity, reservoir depth, carbon dioxide/oil or steam/oil ratios, well drilling and completion unit expenditures, unit operating costs, and fiscal/financial parameters.
- The endogenous EOR component develops reserve-addition and production projections for both thermal EOR and other EOR production (mostly from gas-miscible methods), based on regional oil prices (appropriate to the quality of EOR oil produced) provided interactively by the NEMS system. The endogenous EOR component also projects associated cogeneration capacity and production.

Separate sets of tabular inputs from the exogenous EOR component are used by the endogenous EOR component for the high oil price, low oil price, and technological progress cases. These sets are developed by the exogenous EOR component based on differing assumptions regarding assumed future natural gas prices and rates of technological progress, as appropriate.

Foreign Natural Gas Supply Submodule

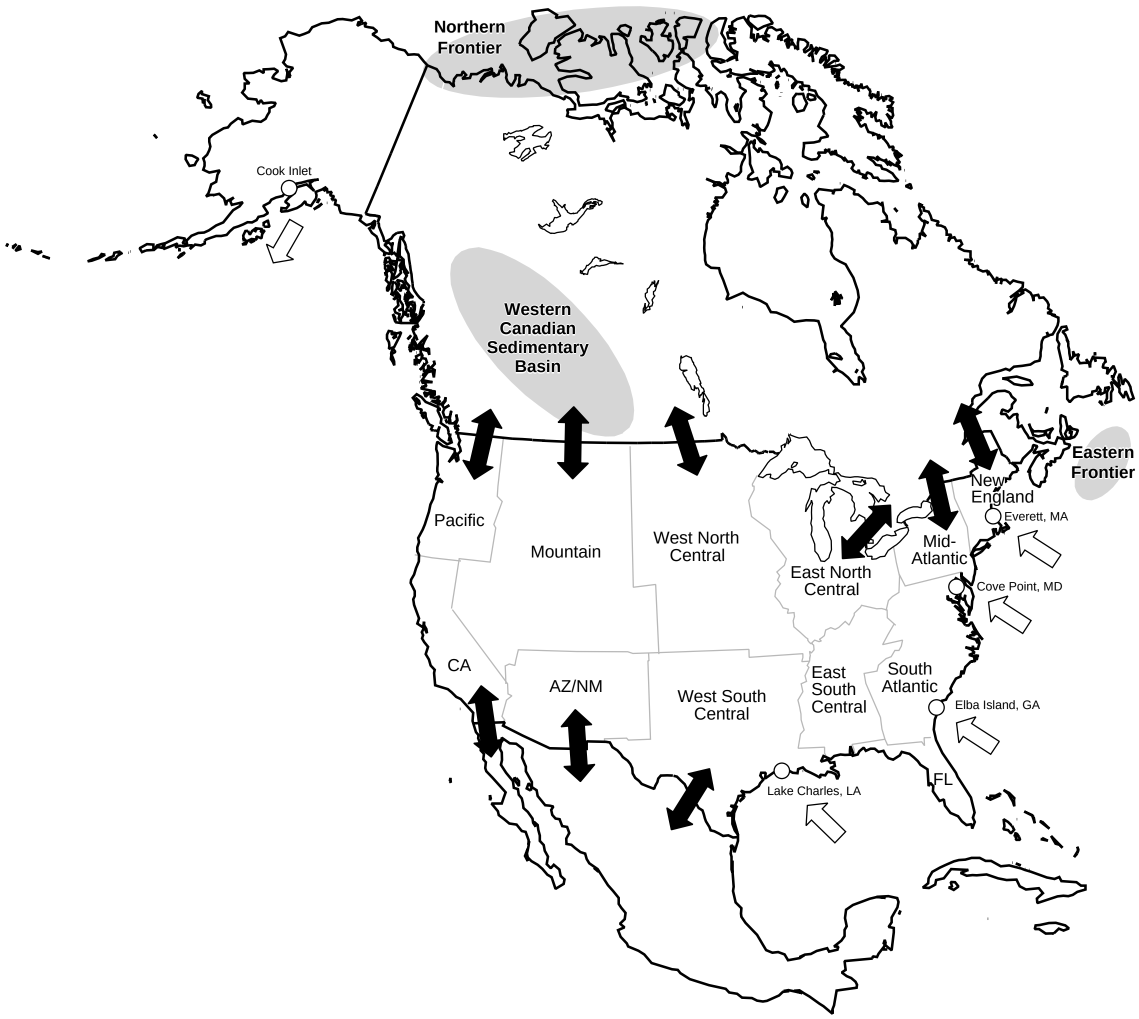
The foreign natural gas supply submodule projects natural gas trade via pipeline as well as liquefied natural gas (LNG) trade. The receiving regions for foreign gas supplies correspond to those of the natural gas integrating framework as established for the natural gas transmission and distribution module. Pipeline natural gas import volumes flow from two sources: Canada and Mexico. U.S. natural gas trade with Canada is represented by six entry/exit points, and trade with Mexico is represented by three entry/exit points (Figure 7).

Net Canadian natural gas supplies to the United States are determined at the six border crossing locations, over a range of gas prices. The initial step is to provide projections of Canadian drilling activity and supply. Canadian demand is then subtracted from supply to determine gas available for export. Gas supply availability is allocated to regional Canadian/U.S. border crossing points by an allocation algorithm that accounts for the associated pipeline capacities and the price responsiveness of supplies at the border points. The determination of the import volumes themselves occurs in the equilibration process of the natural gas transmission and distribution module.

Mexican gas trade is a highly complex issue. A range of noneconomic factors influences, if not determines, flows of gas between the United States and Mexico. The uncertainty is so great that not only is the magnitude of flow for any future year in doubt, but also the direction of flow. Reasonable scenarios have been developed and defended in which Mexico may be either a net importer or exporter of hundreds of billions of cubic feet of gas by 2010. The vast uncertainty and the importance of noneconomic factors in future Mexican gas trade with the United States suggest that these flows should be handled on a scenario basis. Such a scenario can be introduced into the Mexican gas submodule as a user-specified path of future Mexican imports and exports. Otherwise, the analysis uses a prespecified default outlook for Mexican trade, drawn from an assessment of current and expected industry and market circumstances, as indicated in industry announcements or articles and reports in relevant publications. The outlook, regardless of its source, is fixed and is not responsive to energy price changes.

The volume of LNG imports into the United States is projected at four LNG terminals. Imported LNG costs compete with the purchase price of gas prevailing in the vicinity of the import terminal. This is a significant element in evaluating the competitiveness of LNG supplies, since LNG terminals vary greatly in their proximity to domestic producing areas. Terminals close to major consuming markets and far from competing producing areas may provide a sufficient economic advantage to make LNG a competitive gas supply source in some markets. In addition to costs, extensive operational assumptions are required to determine LNG imports/exports. Dominant general factors affecting the outlook include expected developments with respect to the use of existing capacity, expansion at existing sites, and construction at additional locations. The LNG forecast also requires the specification of a combination of factors: available gasification capacity, schedules for and lags between constructing and opening a facility, tanker availability, expected utilization rates, and worldwide liquefaction capacity. For inactive terminals, it is necessary to determine the length of time required to restart operations (normally, between 12 and 18 months). These considerations are taken into account when the economic viability of LNG supplies is determined.

Figure 7. Foreign Natural Gas Trade via Pipeline and Liquefied Natural Gas Terminals



Key:

Solid arrows:	Pipeline entry/exit points.
Open arrows:	Liquefied natural gas terminals.

Natural Gas Transmission and Distribution Module

The natural gas transmission and distribution module (NGTDM) is the component of NEMS that represents the natural gas market. The NGTDM models the natural gas transmission and distribution network in the lower 48 States, which links suppliers (including importers) and consumers of natural gas. The module determines regional market-clearing prices for natural gas supplies (including border prices) and end-use consumption.

The NGTDM has four primary submodules: the annual flow submodule, the capacity expansion submodule, the pipeline tariff submodule, and the distributor tariff submodule. The annual flow submodule—-the central component of the NGTDM—is used to derive flows and prices of natural gas in conjunction with an annual natural gas market equilibrium. Conceptually, the annual flow submodule is a simplified representation of the physical natural gas transmission and distribution system, structured as a network of nodes and arcs. The network representation is in terms of 12 internal nodes and 9 border transshipment nodes (Figure 8). The other three submodules provide parameters to the annual flow submodule that define some of the characteristics of the system's nodes and arcs. Other parameters for defining the natural gas market (such as supply and demand curves) are derived from information passed from other NEMS modules. The capacity expansion submodule provides the annual flow submodule with maximum annual flows allowed along each of the arcs in the network. The pipeline and distributor tariff submodules provide price parameters for establishing the tariffs to be charged along each of the interregional, intraregional, and distribution arcs. Data are also passed back to these submodules from the annual flow submodule and between the other submodules.

The primary outputs from the NGTDM, which are used as input in other NEMS modules, result from establishing a natural gas market equilibrium solution: end-use prices, wellhead and border crossing prices, and associated production, Canadian import, and LNG import levels. In addition, the module provides a forecast of lease and plant fuel consumption and pipeline fuel use, as well as pipeline and distributor tariffs, pipeline and storage capacity expansion, and interregional natural gas flows. Capital investments associated with the expansion of pipeline and storage capacity are also provided. The basic NGTDM structure and its relationship with other NEMS modules is shown in Figure 9. Important inputs and outputs are given below.

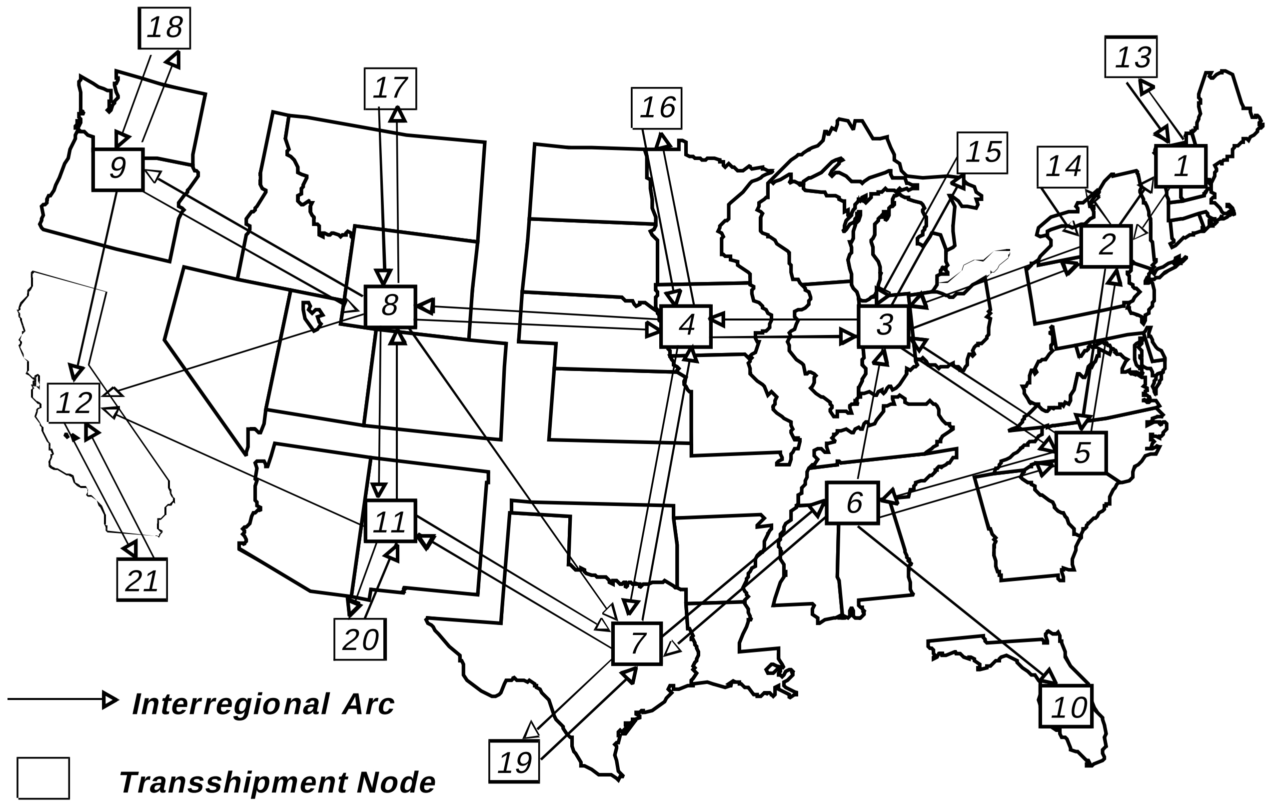
Annual Flow Submodule

The annual flow submodule is the main integrating component of the NGTDM. One of its major functions is to simulate the natural gas price determination process. The annual flow submodule brings together all major economic and technological factors that influence regional natural gas trade in the United States. The economic considerations include the demand for and the supply of natural gas and the competition from imported natural gas.

The annual flow submodule integrates all components of the NGTDM—the annual flow submodule itself, the capacity expansion submodule, the pipeline tariff submodule, and the distributor tariff submodule. Through this integration process, the annual flow submodule derives average annual natural gas prices (wellhead, city gate, and end-use) that reflect a market equilibrium among competing gas supplies, end-use sector consumption, and transportation routes. End-use prices are derived for both core and noncore markets. Within NEMS, the classification of customers is predetermined. It is assumed that core customers purchase firm transportation service and noncore customers purchase interruptible service.

Important NGTDM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
End-use natural gas prices Natural gas wellhead prices Natural gas border crossing prices Domestic natural gas production Canadian natural gas imports and production Lease and plant fuel consumption Pipeline fuel use Pipeline and distribution tariffs Interregional natural gas flows Investment for facilities expansion Storage and pipeline capacity expansion	End-use natural gas demands Natural gas domestic and Canadian supply parameters Natural gas Mexican and LNG import parameters Natural gas exports Consumption parameters from dual-fired plants Macroeconomic variables Associated-dissolved natural gas production	Historical consumption patterns Historical flow patterns Rate design specifications Company-level financial data Pipeline and storage capacity and utilization data Historical end-use prices State and Federal tax parameters Pipeline and storage expansion cost data

Figure 8. Natural Gas Transmission and Distribution Module Network



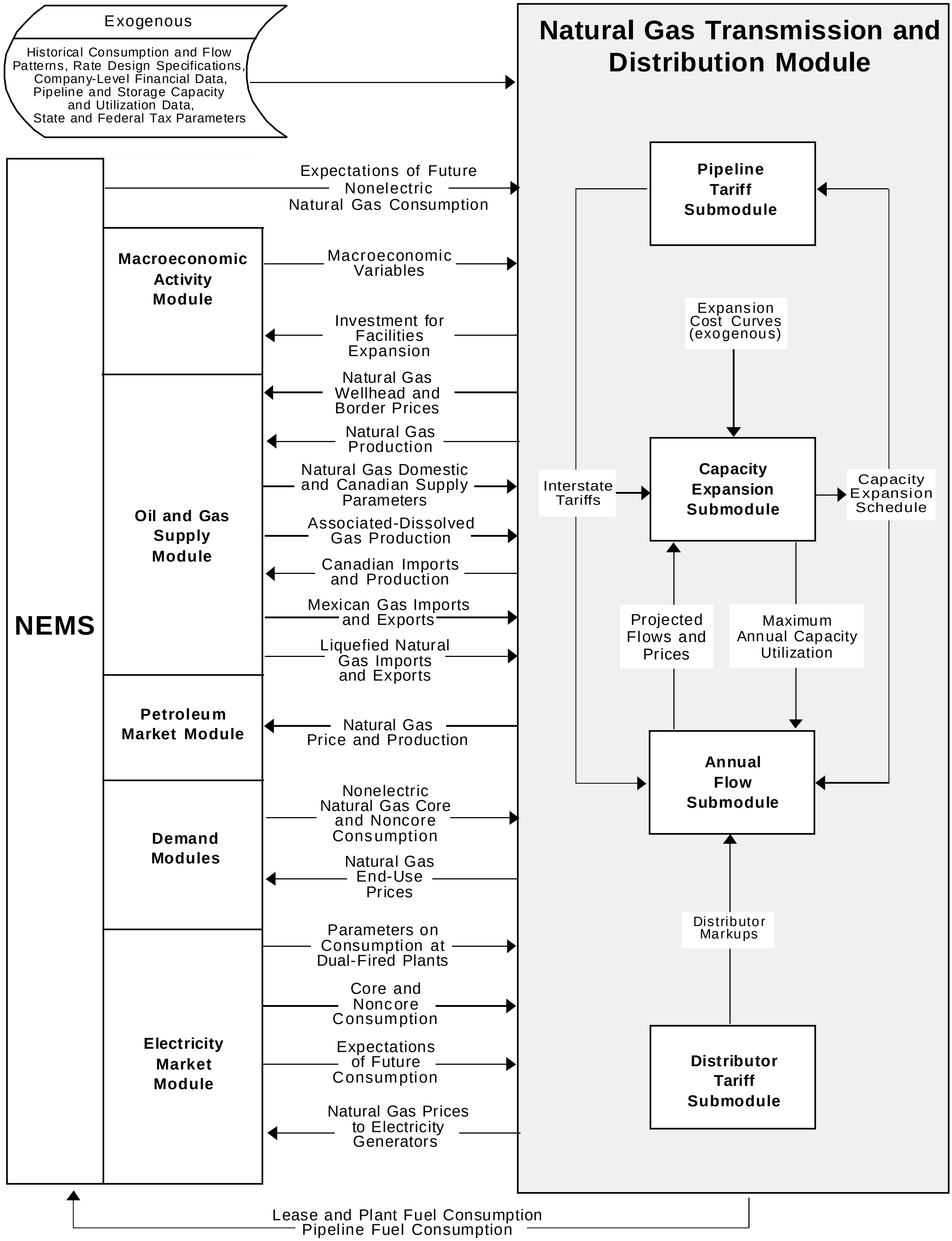
Capacity Expansion Submodule

The capacity expansion submodule simulates the decisionmaking process for expanding pipeline and/or storage capacity in the U.S. gas market. In simulating gas pipeline capacity expansion, the capacity expansion submodule (1) determines the amount of pipeline and storage capacity to be added between or within regions in the NGTDM and (2) establishes effective (or practical) maximum annual utilization rates for each of the interregional pipeline routes represented in the annual flow submodule. Maximum utilization rates (or load factors) for pipeline routes are established to capture the impact of variations in seasonal demand on the maximum amount of gas that can practically flow between regions within a year. Pipeline capacity additions are used in the annual flow submodule (in combination with the maximum load factors) to set limits on annual interregional flows. These capacity additions are also used in the pipeline tariff submodule for the determination of interregional pipeline tariffs.

Pipeline Tariff Submodule

The pipeline tariff submodule computes tariffs for transportation and storage services provided by interstate pipeline companies. The tariffs are computed for individual pipeline companies, then aggregated to the major gas pipeline corridors or arcs (in the United States) specified in the NGTDM network (Figure 8). An accounting system is used to track costs and compute tariffs under various rate design and regulatory scenarios. Tariffs are computed for both firm and interruptible transportation and storage services. Transportation tariffs are computed for the interregional arcs defined by the NGTDM network. These network tariffs represent an aggregation of the tariffs

Figure 9. Natural Gas Transmission and Distribution Module Structure



for individual pipeline companies supplying the network arc. The tariffs are used within the annual flow submodule to derive wellhead, border crossing, and end-use prices and within the capacity expansion submodule to derive capacity additions.

Distributor Tariff Submodule

The distributor tariff submodule assigns the distributor markups charged by local distribution companies for the distribution of natural gas from the city gate to the end user. The submodule determines a volumetric charge that covers the cost of providing distribution or transportation services from the city gate to the end user. This charge represents the difference between the price to the customer and the price to the local distribution company at the city gate. Where end-use service is distinguished by service type (core or noncore), the distributor tariff submodule provides separate core and noncore distribution markups.

Coal Market Module

The coal market module (CMM) represents the mining, transportation, and pricing of coal, subject to end-use demand. Coal supplies are differentiated by heat and sulfur content. The CMM also determines the minimum cost pattern of coal supply to meet exogenously defined U.S. coal export demands as a part of the world coal market. Coal supply is projected on a cost-minimizing basis, constrained by existing contracts. The expansion of existing coal mining capacity is related to the expected domestic and international demand for coal. Twenty-eight different coal types are differentiated with respect to thermal grade, sulfur content, and underground or surface mining. The domestic production and distribution of coal is forecast for 23 demand regions and 16 supply regions (Figures 10 and 11).

The solutions for the components of the CMM are found simultaneously. The sequence of solution among components can be summarized as follows. Coal supply curves are produced by the coal production submodule and input to the coal distribution submodule. Feedback from the coal distribution submodule and other NEMS modules is necessary to project annual mine capacity levels. Given the coal supply curves, distribution costs, and coal demands, the coal distribution submodule projects delivered coal prices. The module is iterated to convergence with respect to equilibrium prices to all demand sectors. Important inputs and outputs are shown below, and the structure of the CMM is shown in Figure 12.

Coal Production Submodule

This submodule produces annual coal supply curves, relating annual production to marginal costs. The supply curves are constructed from a regression analysis of coal production, prices, and costs. A separate supply curve is provided for each mine type (surface or underground), coal type, and supply region. The supply curves are used as inputs to the other submodules.

The factors accounted for in constructing the supply curves are reserve depletion, capacity utilization, leadtime constraints on the opening of new mines, labor productivity, and real labor and fuel costs. A different set of supply curves is constructed for each year in the forecast period.

Coal Distribution Submodule

The coal distribution submodule is a linear program that determines the least-cost supplies of coal for a given set of coal demands by demand sector and region, accounting for costs from different supply regions, coal characteristics, and existing coal supply contracts.

Coal transportation costs are simulated using inter-regional coal transport costs derived by subtracting reported minemouth costs from reported delivered costs. Shipping costs are adjusted through the forecast period by mode-specific trends in factor input costs, such as labor productivity and fuel cost charges.

Coal Export Submodule

The coal export submodule determines the quantities of coal imported and exported from the United States. The quantities are determined within a world trade context, based on user-provided characteristics of foreign coal supply and demand. The submodule disaggregates coal into 16 coal export regions and 20 import regions, as shown on the following page.

Important CMM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Coal production and distribution Minemouth coal prices End-use coal prices Coal exports Transportation rates Coal quality by source, destination, and end-use sector	Coal demand by sector Interest rates Price deflators Diesel fuel prices	Base year production Contract quantities Labor productivity Labor costs Transportation costs Coal production capacity International transportation costs International supply curves Labor cost escalators Demand for U.S. coal exports Demand for U.S. coal imports

Coal Export Regions		Coal Import Regions	
U.S. East Coast	South Africa	U.S. East Coast	Iberia
U.S. Gulf Coast	Poland	U.S. Gulf Coast	Italy
U.S. Southwest and West	CIS (Europe)	U.S. Northern Interior	Mediterranean and Eastern Europe
U.S. Northern Interior	CIS (Asia)	U.S. Noncontiguous	Mexico
U.S. Noncontiguous	China	Eastern Canada	South America
Australia	Colombia	Interior Canada	Japan
Western Canada	Indonesia	Scandinavia	East Asia
Interior Canada	Venezuela	United Kingdom and Ireland	Hong Kong
		Germany	ASEAN (Association of South East Asia Nations)
		Other Northwestern Europe	India and South Asia

Figure 10. Coal Market Module Demand Regions

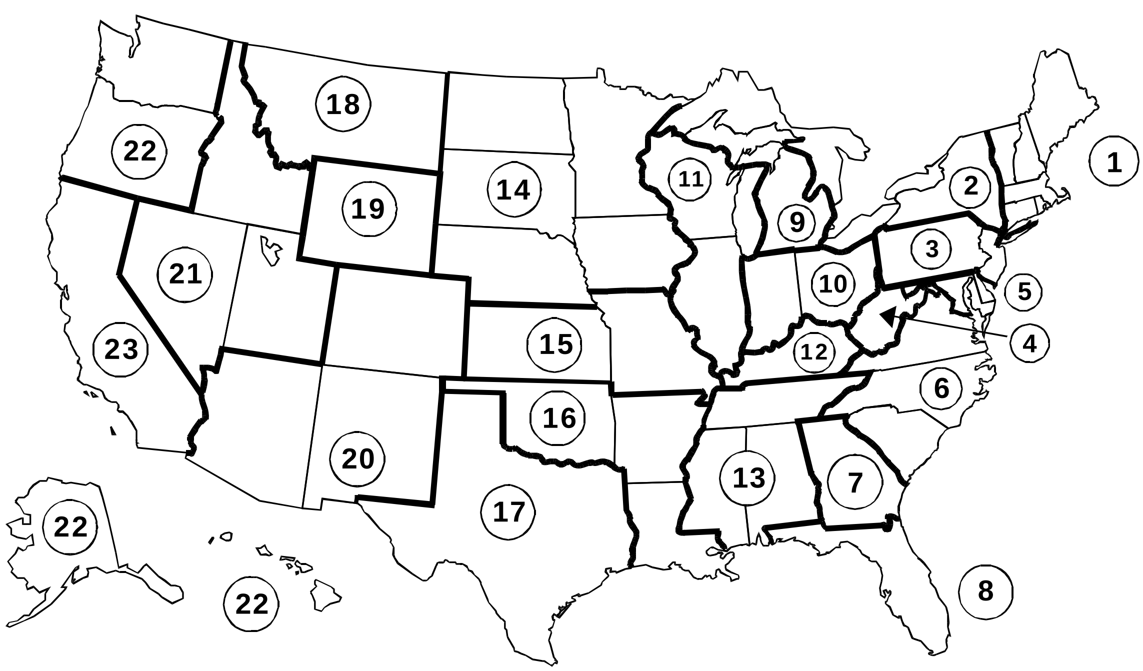
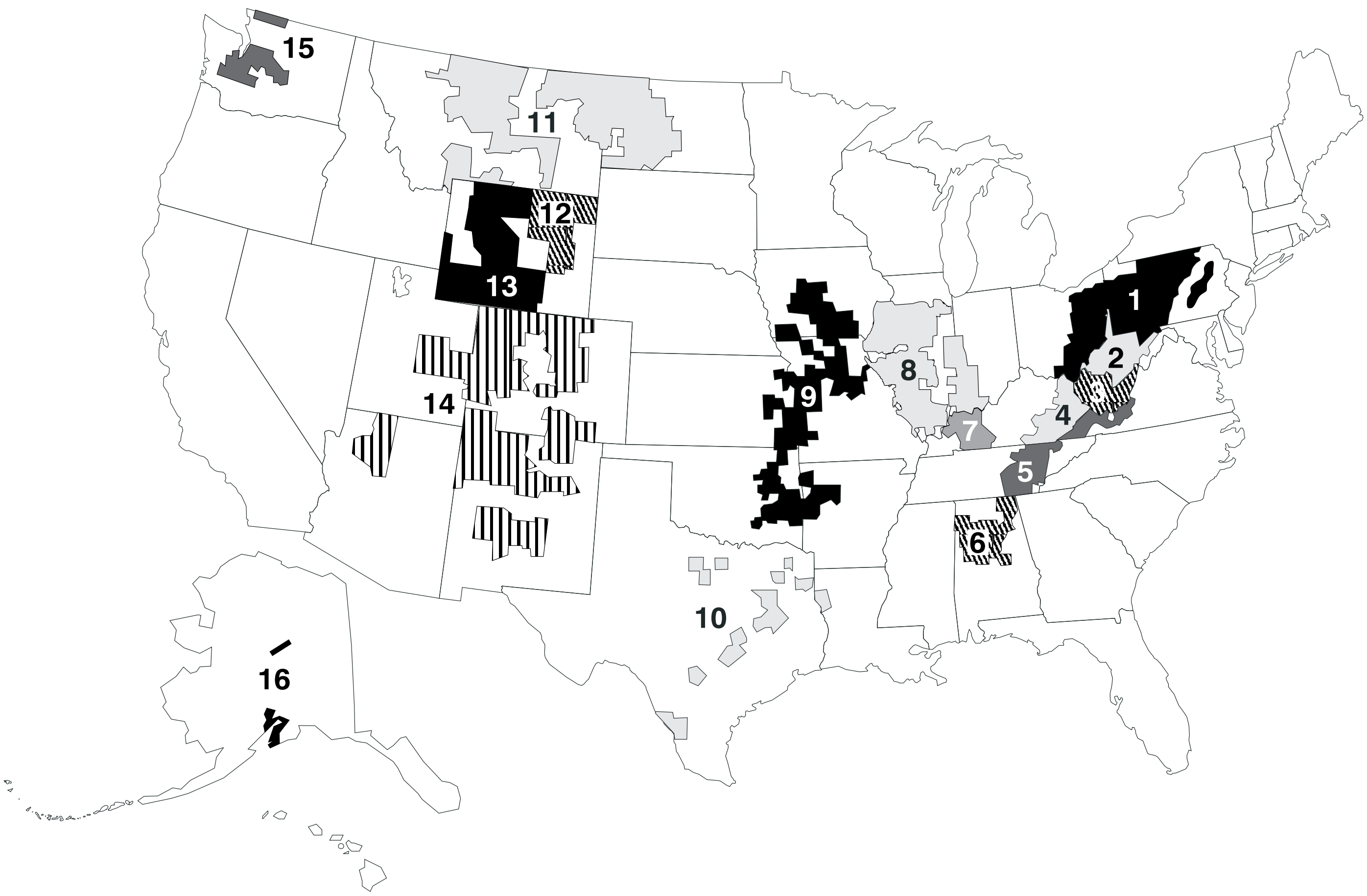
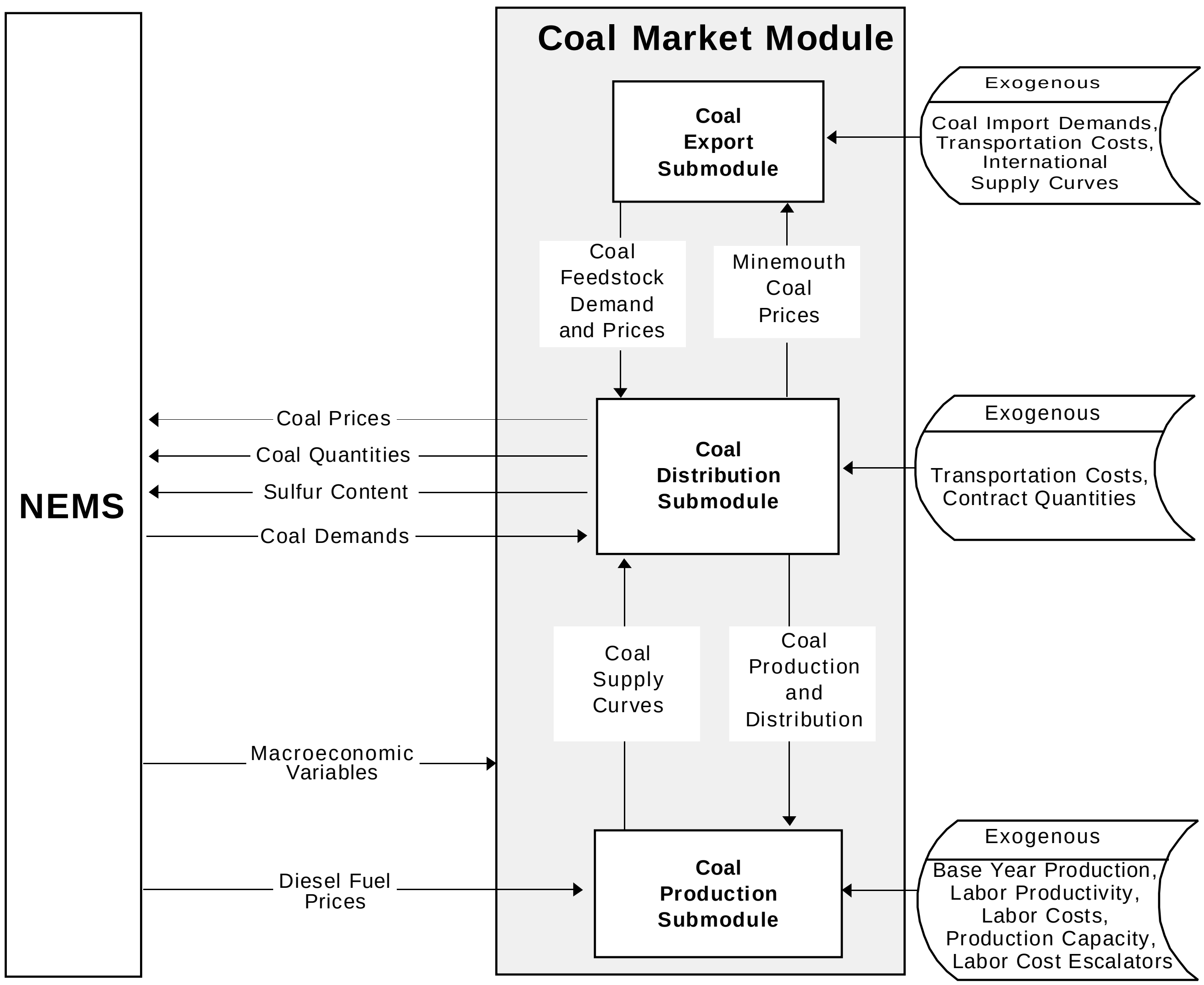


Figure 11. Coal Market Module Supply Regions



Region		Definition
Northern Appalachia	1	Pennsylvania, Maryland, and Ohio
	2	West Virginia (north)
Southern Appalachia	3	West Virginia (south)
	4	Kentucky (east)
	5	Virginia and Tennessee
	6	Alabama
Interior	7	Kentucky (west)
	8	Illinois and Indiana
	9	Arkansas, Iowa, Kansas, Missouri, and Oklahoma
	10	Texas and Louisiana
North Great Plains	11	North Dakota, South Dakota, and Montana
	12	Wyoming (east)
	13	Wyoming (west)
Other West	14	Arizona, New Mexico, Colorado, and Utah
	15	Washington, Oregon, and California
Alaska	16	Alaska

Figure 12. Coal Market Module Structure



The export submodule is a linear program that determines world coal trade distribution by minimizing overall costs for coal, subject to U.S. coal supply prices and a number of constraints. Supply costs (mining and preparation plus transportation) for each coal export region, coal type, and end use compete in two demand sectors (coking and steam). The submodule also takes into account limits on sulfur dioxide emissions and concerns about diversity of coal sources.

Renewable Fuels Module

The renewable fuels module (RFM) consists of six submodules and a hydroelectric power plant file that represent the various types of renewable energy (Figure 13). Since most renewables (wind, solar, and geothermal) are used to generate electricity, the interaction with the electricity market module (EMM) is important for modeling grid-connected renewable-electric applications. On the other hand, many renewables are especially well suited for off-grid applications or distributed generation at the point of end use. In the current version of the RFM, only central station grid-connected applications are modeled endogenously; data on distributed applications are input exogenously. The penetration of grid-connected generation technologies, with the exception of municipal solid waste, is determined by the EMM. Biomass can also be used to produce liquid fuels such as ethyl alcohol (ethanol). Therefore, a primary NEMS interaction of the RFM is with the petroleum market module, which determines refinery demand for ethanol as a gasoline blending component.

Each submodule of the RFM is solved independently of the rest. Because variable operation and maintenance costs for renewable technologies are lower than for any other major generating technologies and they produce almost no air pollution, all available renewable generating capacity is dispatched first by the EMM.

Wind-Electric Submodule

The wind-electric submodule projects the availability of wind resources as well as the cost and performance of wind turbine generators. This information is passed to the EMM so that wind turbines can be built and dispatched in competition with other electricity generating technologies. The wind turbine data are expressed in the form of energy supply curves that provide the maximum amount of turbine generating capacity that could be installed, given the available land area, wind speed, and capacity factor.

Geothermal-Electric Submodule

The geothermal-electric submodule provides the EMM with forecasts of new geothermal capacity that can be built, along with related cost and performance data. The data are expressed in the form of a supply curve that represents the aggregate amount of new capacity and associated costs that can be offered from each geothermal site. The principal factor determining how much can be offered is the amount of previously installed capacity relative to the total potential capacity for the site, based on the historical experience of geothermal development at existing sites.

Geothermal resource data are based on Sandia National Laboratory's 1991 geothermal resource assessment. Only hydrothermal (hot water and steam) resources are considered. Hot dry rock resources are not included, because they are not expected to be exploited during the NEMS time frame.

Capital and operating costs are estimated separately, and life-cycle costs are calculated according to standardized NEMS assumptions. The costing methodology includes ways to analyze effects of Federal and State energy tax construction and production incentives (if any). Individual reservoirs and their sizes and locations are mapped and matched to the NEMS electricity supply regions (see Figure 15 on page 33).

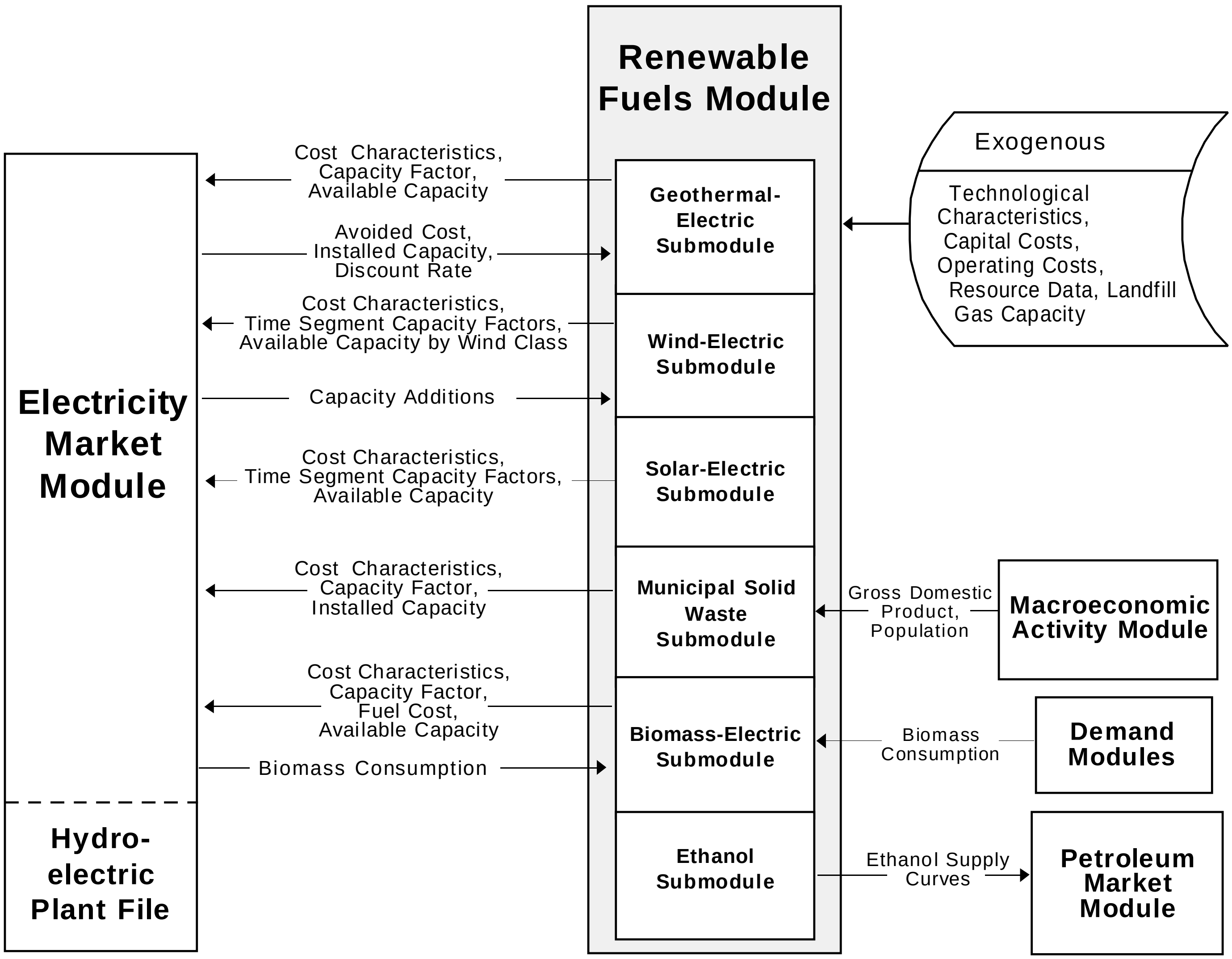
Solar-Electric Submodule

The solar-electric submodule models both solar-photovoltaic and thermal-electric installations. Only central station grid-connected applications constructed by a utility or independent power producer are considered as generators. Grid-connected solar facilities can be utility or nonutility, a distinction that is internal to the EMM. The required input information is identical.

Capacity projections are developed endogenously by competing them against other generating technologies on the basis of capital costs, capacity factors, and fixed and variable operation and maintenance costs. Solar energy is a form of renewable energy that requires

Important RFM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Energy production capacities Capital costs Operating costs (including wood supply prices for the wood submodule) Ethanol supply curves Capacity factors for solar-thermal, solar-photovoltaic, and wind-electric	Installed energy production capacity Gross domestic product Interest rates Avoided cost of electricity	Site-specific geothermal resource quality data Agricultural feedstock data (biofuels submodule) Site-specific wind resource quality data Plant utilization (capacity factor) Technology cost and performance parameters Landfill gas capacity

Figure 13. Renewable Fuels Module Structure



a more detailed characterization to represent its regionality and intermittent nature. This is dealt with by the regional load shapes used by the EMM and different seasonal and daily time periods to represent intermittency.

Biofuels (Ethanol) Submodule

This requirement is addressed, first, by the regional load shapes used by the EMM and, second, by the different seasonal and daily time periods used to represent intermittency. This submodule employs supply functions (cost versus quantity) by Petroleum Administration for Defense District (see Figure 17 on page 37) for ethanol produced from corn. Agricultural feedstock production quantities and costs are provided exogenously from a U.S. Department of Agriculture linear programming model, the Agricultural Resources Interregional Modeling System. The supply curves take into account feedstock costs, feedstock conversion costs, and energy prices. The supply functions are used by the petroleum market module to compute regional demands for ethanol.

Biomass-Electric Submodule

The biomass submodule provides forecasted wood fuel prices and technology characterization information (capital costs, operating costs, capacity factors, etc.) for the EMM, thereby allowing biomass-fueled power plants to compete with other electricity generating technologies. Wood fuel prices are represented by a supply curve constructed according to the accessibility of wood resources to the electricity generation sector.

The supply curve employs wood resource inventory and cost data from the U.S. Forest Service, as well as quantity and cost information for dedicated energy crops. Fuel distribution and preparation cost data are built into these curves. The supply schedule biomass prices are combined with other variable operating costs associated with burning biomass. The aggregate variable cost is then passed to the EMM.

Dispersed consumption of wood energy is modeled in the industrial, commercial, and residential demand modules.

Municipal Solid Waste Submodule

The municipal solid waste (MSW) submodule provides annual projections of energy produced from the incineration of MSW. It uses the quantity of MSW produced (derived from an econometric equation that uses gross domestic product and population as the forecast drivers), the heating value of a pound of MSW, and shares of MSW combusted for energy recovery. In addition, the submodule supplies the EMM with capital and operating cost information, which is used only for calculations of electricity prices. MSW energy production does not compete with other electricity generating technologies, because MSW is viewed as a byproduct of a community's waste disposal activities rather than a competitive alternative to other fuels. An exogenous projection of landfill gas-fueled generating capacity is added to the projection before it is passed to the EMM.

Hydroelectric Plant File

Conventional hydroelectric power is not modeled, and the hydroelectric plant file is now resident in the EMM and not the RFM. The hydroelectric plant file provides currently available and planned regional hydropower capacity and capacity factors for conventional hydroelectric facilities. This plant information is supplied by aggregating the responses of utility and nonutility power producers to annual EIA power plant surveys (Forms EIA-860, "Annual Electric Generator Report;" EIA-759, "Monthly Power Plant Report;" and EIA-867, "Annual Nonutility Power Producer Report"). The emphasis of the file is on planned hydroelectric capacity additions and reductions. Unplanned capacity changes can be handled by making offline capacity adjustments based on assumptions for hydropower relicensing, water availability, land use and environmental regulations, and electricity demand growth.

Electricity Market Module

The electricity market module (EMM) represents the generation, transmission, and pricing of electricity, subject to: delivered prices for coal, petroleum products, natural gas, and synthetic fuels; the cost of centralized generation from renewable fuels; macroeconomic variables for costs of capital and domestic investment; and electricity load shapes and demand. The submodules consist of capacity planning, fuel dispatching, finance and pricing, and load and demand-side management (Figure 14). In addition, nonutility supply and electricity trade are represented in the fuel dispatching and capacity planning submodules. Nonutility generation from cogenerators and other facilities whose primary business is not electricity generation is represented in the demand and fuel supply modules. All other nonutility generation is represented in the EMM. The generation of electricity is accounted for in 15 supply regions (Figure 15), and fuel consumption is allocated to the 9 Census divisions.

Operating (dispatch) decisions are provided by the cost-minimizing mix of fuel and variable operating and maintenance (O&M) costs, subject to environmental costs. Capacity expansion is determined by the least-cost mix of all costs, including capital, O&M, and fuel. Construction of generating plants with long leadtimes is selected with planning horizons up to six periods into the future; the planning horizon can change with respect to the generating technology being considered. Electricity demand is represented by load curves, which vary by region, season, and time of day. The shape of load curves is also affected by the penetration of demand-side management programs.

The solution to the submodules of the EMM is simultaneous in that, directly or indirectly, the solution for each submodule depends on the solution to every other submodule. Important inputs and outputs are shown below. A solution sequence through the submodules can be viewed as follows:

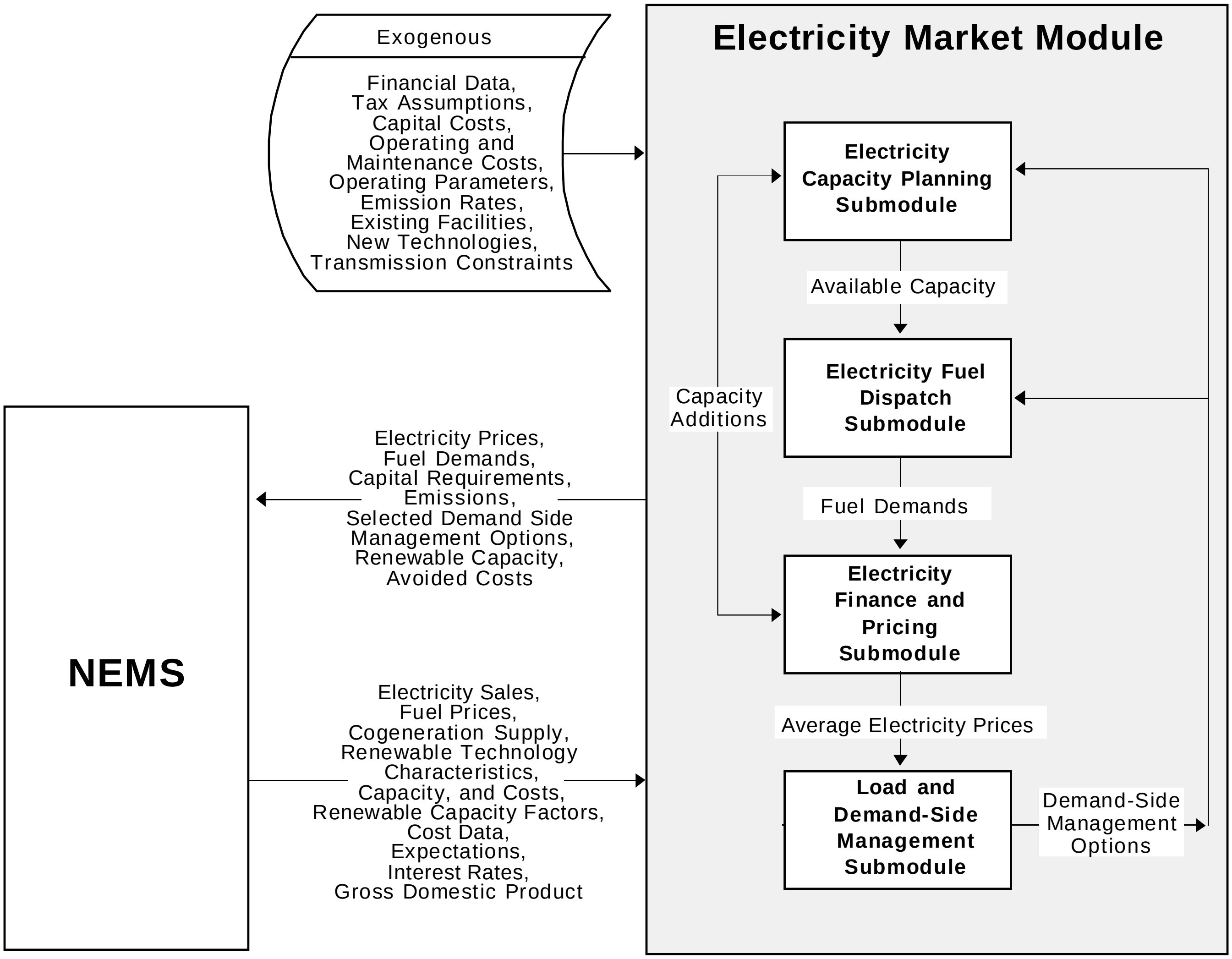
- The load and demand-side management submodule processes electricity demand to construct load curves and provides the costs and impacts of demand-side management programs.
- The electricity capacity planning submodule projects the construction of new utility and nonutility plants, the penetration of demand-side management programs, the level of firm power trades, and the addition of scrubbers for environmental compliance.
- The electricity fuel dispatch submodule dispatches the available generating units, both utility and nonutility, allowing surplus capacity in select regions to be dispatched for another region's needs (economy trade).
- The electricity finance and pricing submodule calculates total revenue requirements for each utility operation and computes average electricity prices.

Electricity Capacity Planning Submodule

The electricity capacity planning (ECP) submodule determines how best to meet expected growth in electricity demand, given available resources, expected load shapes, expected demands and fuel prices, environmental constraints, and costs for utility and nonutility technologies. When new capacity is required to meet electricity demand, then the timing of the demand increase, the expected utilization of the new capacity, the operating efficiencies and the construction and operating costs of available technologies determine what technology is chosen. The ownership of the facility (utility or nonutility) influences the decision, because the capital costs differ according to the type of ownership due to different capital structures.

Important EMM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Electricity prices and price components	Electricity sales	General financial data
Fuel demands	Fuel prices	Tax assumptions
Capital requirements	Cogeneration supply	Capital costs
Emissions	Renewable technology characteristics and capacity	Operation and maintenance costs
Demand-side management options	Renewable capacity factors	Operating parameters
	Gross domestic product	Emissions rates
	Interest rates	New technologies
		Existing facilities
		Transmission constraints

Figure 14. Electricity Market Module Structure



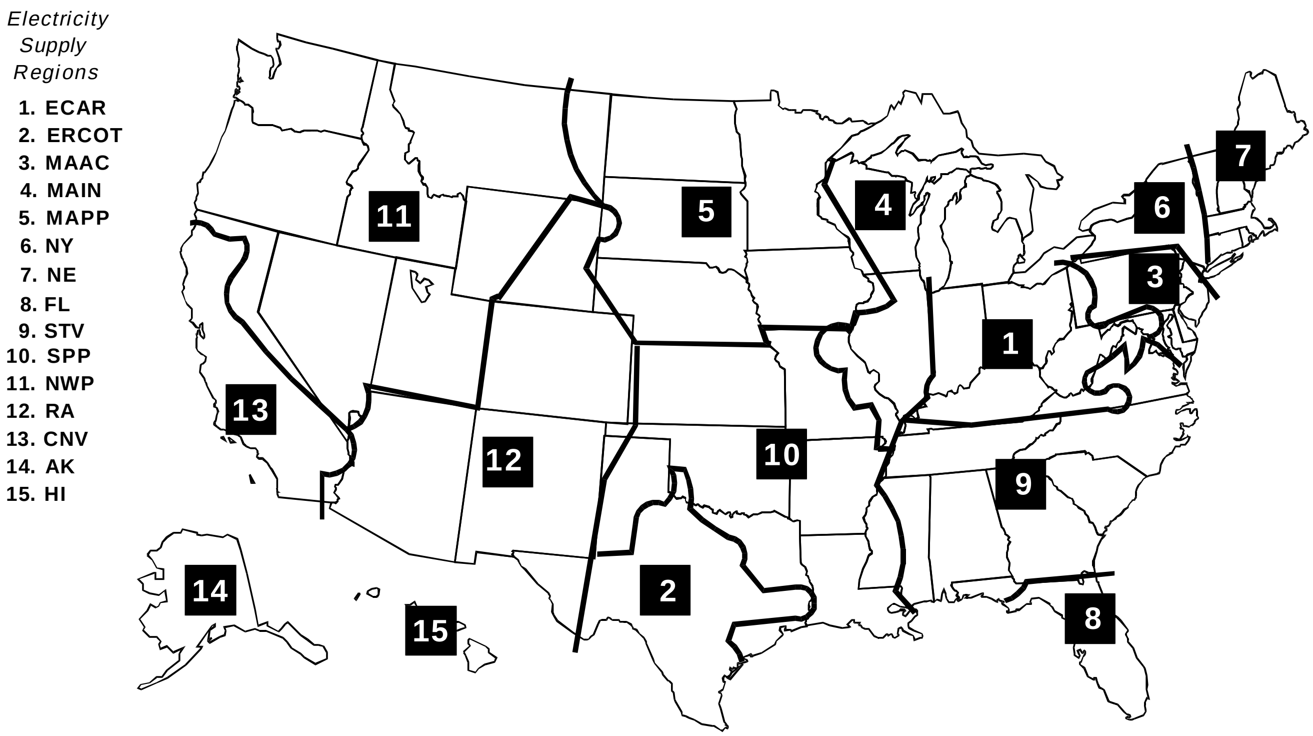
The expected utilization of the capacity is important in the decisionmaking process. A technology with relatively high capital costs but comparatively low operating costs (primarily fuel costs) may be the appropriate choice if the capacity is expected to operate continuously (base load). However, a plant type with high operating costs but low capital costs may be the most economical selection to serve the peak load (i.e., the highest demands on the system), which occurs infrequently. Intermediate or cycling load occupies a middle ground between base and peak load and is best served by plants that are cheaper to build than baseload plants and cheaper to operate than peak load plants.

Technologies are compared on the basis of total capital and operating costs incurred over a 30-year period. As new technologies become available, they are competed against conventional plant types. Fossil-fuel, nuclear, and renewable generating technologies are represented.

The timing of the demand increase is important, because the construction leadtimes of technologies differ. The ECP submodule looks up to six periods into the future when identifying new capacity needs. A multiperiod optimization is performed, whereby capacity choices in each year are made by looking at several years in the future rather than a single year.

Construction lead times also contribute to uncertainty about investment decisions. Technologies with long leadtimes are subject to greater financial risk. Compared to plants with shorter leadtimes, they are

Figure 15. Electricity Market Module Supply Regions



more sensitive to market changes in interest and inflation rates and are more vulnerable to uncertain demand projections that determine the need for new capacity. To capture these factors, the discount rate for each technology is adjusted using risk premiums based on the construction leadtime. The risk-adjusted discount rate results in the perception that a technology with a long leadtime is less economically attractive than another technology with similar costs, but a shorter leadtime.

Uncertainty about investment costs for new technologies is captured in the ECP using technological optimism and learning factors. The technological optimism factor reflects the inherent tendency to underestimate costs for new technologies. The degree of technological optimism depends on the complexity of the engineering design and the stage of development. As development proceeds and more data become available, cost estimates become more accurate and the technological optimism factor declines. Learning factors represent reductions in capital costs due to "learning-by-doing."

Initially, investment decisions are determined in the ECP using cost and performance characteristics that are represented as single point estimates corresponding to the average (expected) cost. However, these parameters are also subject to uncertainty and are better represented by distributions. If the distributions of two or more options overlap, the option with the lowest average cost is not likely to capture the entire market. Therefore, the ECP uses a market-sharing algorithm to adjust the initial solution and reallocate some of the capacity expansion decisions to technologies that are "competitive" but do not have the lowest average cost.

The ECP submodule also determines whether to contract for unplanned firm power imports from Canada and from neighboring electricity supply regions. Imports from Canada are competed using supply curves developed from cost estimates for potential hydroelectric projects in Canada. Imports from neighboring electricity supply regions are competed in the ECP based on the cost of the unit in the exporting region plus the additional cost of transmitting the power.

After building new capacity, the submodule passes total available capacity to the electricity fuel dispatch submodule and new capacity expenses to the electricity finance and pricing submodule. The following technologies are considered:

Fossil Fired
Coal without FGD (SO_2 standard ≤ 1.2 lb/MMBtu)
Coal without FGD (SO_2 standard ≤ 2.5 lb/MMBtu)
Coal without FGD (SO_2 standard ≤ 3.34 lb/MMBtu)
Coal without FGD (SO_2 standard > 3.34 lb/MMBtu)
Coal with FGD (SO_2 standard ≤ 1.2 lb/MMBtu)
Coal with FGD (SO_2 standard ≤ 2.5 lb/MMBtu)
Coal with FGD (SO_2 standard ≤ 3.34 lb/MMBtu)
Coal with FGD (SO_2 standard > 3.34 lb/MMBtu)
New pulverized coal with FGD
Advanced clean coal technology
Gas/oil steam
Conventional gas/oil combined cycle
Advanced combined cycle
Conventional combustion turbine
Advanced combustion turbine
Fuel cells
(FGD = flue gas desulfurization, lb/MMBtu = pounds per million Btu.)

Nuclear
Conventional nuclear
Advanced nuclear

Renewables
Conventional hydropower
Pumped storage hydropower
Geothermal
Solar-thermal
Solar-photovoltaic
Wind
Wood
Municipal solid waste

Electricity Fuel Dispatch Submodule

Given available capacity, firm purchased-power agreements, fuel prices, and load curves, the electricity fuel dispatch (EFD) submodule minimizes variable costs as it solves for generation facility utilization and economy power exchanges to satisfy demand in each time period and region. The submodule uses merit order dispatching; that is, utility, independent power producer, and small power producer plants are dispatched until demand is met in a sequence based on their operating costs, with least-cost plants being operated first. Limits on emissions of sulfur dioxide from generating units and the engineering characteristics of units serve as constraints. During off-peak periods, the submodule institutes load following, which is the practice of running plants near their minimum operating levels rather than shutting them down and incurring shutoff and startup costs. In addition, to account for scheduled and unscheduled maintenance, the capacity of each plant is derated (lowered) to the expected availability level. Finally, the operation of utility and nonutility plants for each region is simulated over six seasons to reflect the seasonal variation in electricity demand.

Interregional economy trade is also represented in the EFD submodule by redetermining the dispatch decision and allowing surplus generation in one region to satisfy electricity demand in an importing region, resulting in a cost savings. Economy trade with Canada is determined in a similar manner as interregional economy trade. Surplus Canadian energy is allowed to displace energy in an importing region if it results in a cost savings. After dispatching, fuel use is reported back to the fuel supply modules, operating expenses and revenues from trade are reported to the electricity finance and pricing submodule, and emissions are reported to the integrating module.

Electricity Finance and Pricing Submodule

The costs of building capacity, instituting demand-side management programs, buying power, and generating electricity are tallied in the electricity finance and pricing (EFP) submodule, which simulates the cost-of-service method often used by State regulators to determine the price of electricity. Using historical costs for existing plants (derived from various sources such as Federal Energy Regulatory Commission (FERC) Form 1, “Annual Report of Major Electric Utilities, Licensees and Others,” and Form EIA-412, “Annual Report of Public Electric Utilities”), cost estimates for new plants, fuel prices from the NEMS fuel supply modules, unit operating levels, demand-side management program costs, plant decommissioning costs, plant phase-in costs, and purchased power costs, the EFP submodule calculates total revenue requirements for each area of utility operation—generation, transmission, and distribution. Revenue requirements shared over sales by customer class yield the price of electricity for each class. Electricity prices are returned to the demand modules. In addition, the submodule generates detailed financial statements. The EFP is also in the process of being modified to consider alternative methods for pricing electricity in a restructured, competitive electric power industry.

Load and Demand-Side Management Submodule

The load and demand-side management (LDSM) submodule generates load curves representing the demand for electricity and develops data on the costs and impacts of specific demand-side management programs. The demand for electricity varies over the course of a day. Many different technologies and end-uses, each requiring a different level of capacity for different lengths of time, are powered by electricity. For operational and planning analysis, an annual load duration curve, which represents the aggregated hourly demands, is constructed. Because demand varies by geographic area and time of year, the LDSM submodule generates load curves for each region and season.

The LDSM submodule evaluates utility-sponsored demand-side management programs, which attempt to alter the load curves by reducing or shifting demand. The submodule determines which programs are competitive and then passes the determination to the ECP submodule for competition against supply options. (The demand modules of NEMS also model some price-induced conservation programs by accounting for the penetration of more efficient end-use technologies in each sector.) If the ECP submodule selects demand-side management programs to meet the demand for electricity, the programs that penetrate are passed back to the demand modules so that their impacts are reflected in the future demands for electricity.

Emissions

The EMM tracks emission levels for sulfur dioxide (SO_2) and nitrogen oxides (NO_x). Facility development, retrofitting, and dispatch are constrained to comply with the pollution constraints of the Clean Air Act Amendments of 1990 (CAAA90) and other pollution constraints. An innovative feature of this legislation is a system of trading emissions allowances. The trading system allows a utility with a relatively low cost of compliance to sell its excess compliance (i.e., the degree to which its emissions per unit of power generated are below maximum allowable levels) to utilities with a relatively high cost of compliance. The trading of emissions allowances does not change the national aggregate emissions level set by CAAA90, but it does tend to minimize the overall cost of compliance.

Petroleum Market Module

The petroleum market module (PMM) represents domestic refinery operations and the marketing of petroleum products to consumption regions. The PMM solves for petroleum product prices, crude oil and product import activity (in conjunction with the international energy module), and domestic refinery capacity expansion and fuel consumption. The solution is derived, satisfying the demand for petroleum products and incorporating the prices for raw material inputs and imported petroleum products, the costs of investment, and the domestic production of crude oil and natural gas liquids. Important PMM inputs and outputs are given below. The relationship of the PMM to other NEMS modules is illustrated in Figure 16.

The PMM is a regional, linear-programming representation of the U.S. petroleum market. Refining operations are represented by linear programming formulations for each of five Petroleum Administration for Defense Districts (PADDs) (Figure 17). Each PADD is treated as a single firm where more than 30 distinct refinery processes are modeled. Refining capacity is allowed to expand in each region, but the model does not distinguish between additions to existing refineries or the building of new facilities. Investment criteria are developed exogenously, although the decision to invest is endogenous.

The PMM assumes that the petroleum refining and marketing industry is competitive. The market will move toward lower-cost refiners who have access to crude oil and markets. The selection of crude oils, refinery process utilization, and logistics (transportation) will adjust to minimize the overall cost of supplying the market with petroleum products. Although the petroleum market responds to pressure, it rarely strays from the underlying refining costs and economics for long periods of time. If demand is unusually high in one region, the price will increase, driving down demand and providing economic incentives for bringing supplies in from other regions, thus restoring the supply/demand balance.

Existing regulations concerning product types and specifications, the cost of environmental compliance, and Federal and State taxes are also modeled. The PMM incorporates taxes imposed by the 1993 Budget Reconciliation Act as well as costs resulting from the Clean Air Act Amendments of 1990 (CAAA90) and other environmental legislation. The costs of producing new formulations of gasoline and diesel fuel as a result of the CAAA90 are determined within the linear programming representation by incorporating specifications and demands for these fuels.

An important innovation in the NEMS involves the relationship between the domestic and international markets. Whereas earlier models postulated entirely exogenous prices for oil on the international market (the world oil price), NEMS includes an international energy module that estimates supply curves for imported crude oils and products based on, among other factors, U.S. participation in international trade.

Regions

The PMM models U.S. crude oil refining capabilities based on the five PADDs which were established during World War II and are still used by EIA for data collection and analysis. The use of PADD data permits the PMM to take full advantage of EIA's historical database and allows analysis and forecasting within the same framework as the petroleum industry uses.

Important PMM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Petroleum product prices	Petroleum product demand by sector	Processing unit operating parameters
Crude oil imports and exports	Domestic crude oil supply curves	Processing unit capacities
Crude oil production	World oil price	Product specifications
Petroleum product imports and exports	International crude oil supply curves	Operating costs
Refinery activity and fuel use	International product supply curves	Capital costs
Cogeneration	International oxygenates supply curves	Transmission and distribution costs
Natural gas plant liquids production	Ethanol supply curves	Federal and State taxes
Processing gain	Natural gas prices	Cogeneration unit operating parameters
Capacity additions	Electricity prices	Cogeneration unit capacities
Capital expenditures	Natural gas production	
Revenues	Macroeconomic variables	

Figure 16. Petroleum Market Module Structure

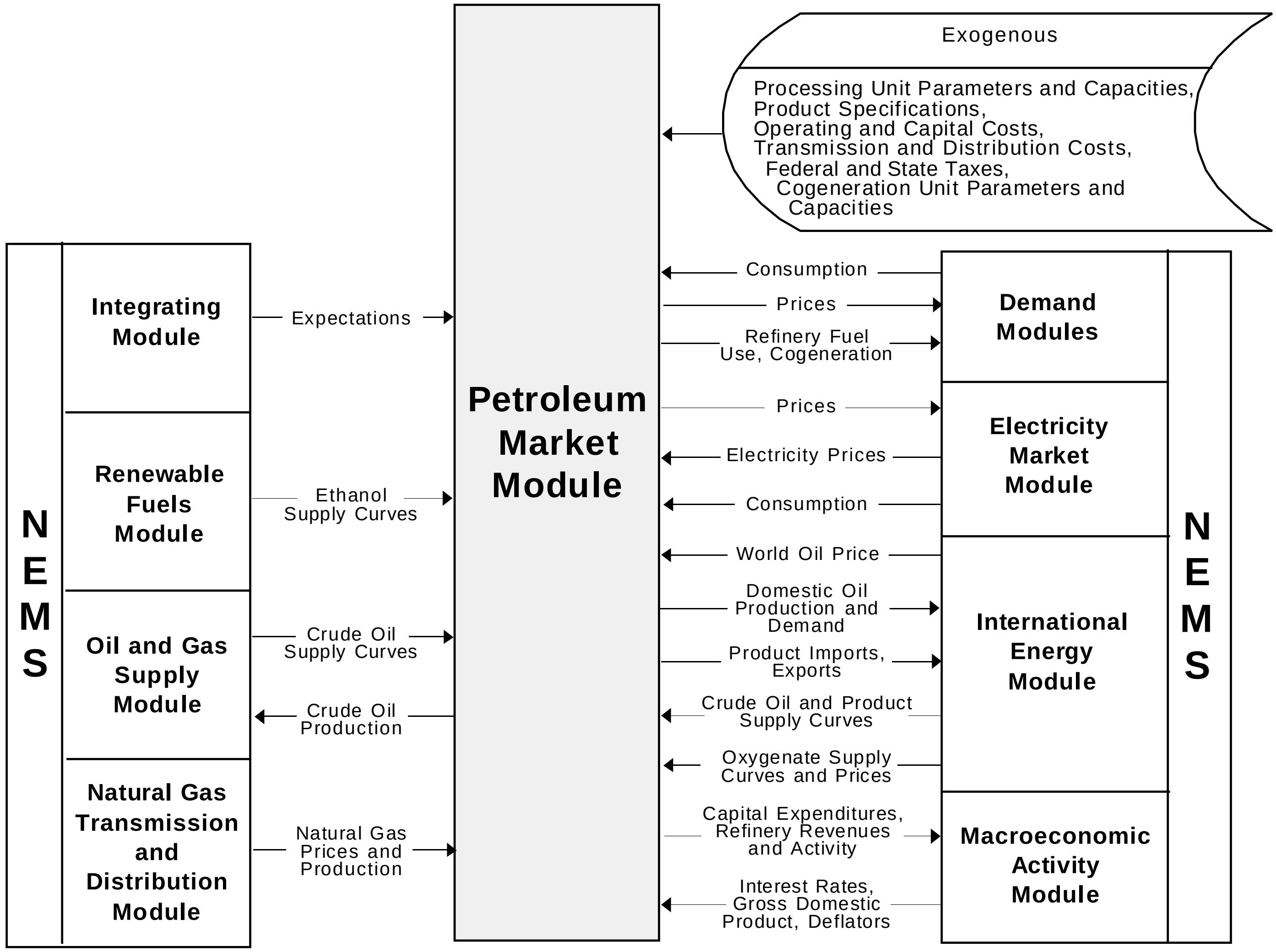


Figure 17. Petroleum Administration for Defense Districts

Product Categories

Product categories, specifications, and recipe blends modeled in PMM include the following:

Motor gasoline: traditional unleaded, oxygenated (2.7%), reformulated (2.0%), reformulated/high oxygen (2.7%).

Jet fuels: kerosene-based.

Distillates: kerosene, heating oil, highway diesel.

Residual fuels: low-sulfur, high-sulfur.

Liquefied petroleum gas (LPG): propane, LPG mixes.

Petrochemical feedstocks: petrochemical naphtha, petrochemical gas oil, propylene, aromatics.

Others: asphalt and road oil, still gas, petroleum coke, lubricating products and waxes, special naphthas.

Fuel Use

PMM determines refinery fuel use by PADD for purchased electricity, natural gas, distillate fuel, residual fuel, liquefied petroleum gas, and other petroleum. The fuels (natural gas, petroleum, other gaseous fuels, and other) consumed within the refinery to generate electricity from cogeneration facilities are also measured.

Crude Oil Categories

Both domestic and imported crude oil are aggregated into five categories, as defined by the following ranges of gravity and sulfur:

Category	Sulfur	Gravity
Low-sulfur light	0-0.5%	>24
Medium-sulfur heavy	0.35-1.1%	>24
High-sulfur light	>1.1%	>32
High-sulfur heavy	>1.1%	24-33
High-sulfur very heavy	>0%	<23

This aggregation of crude oil types allows the PMM to account for changes in crude oil composition over time. A "composite" crude with the appropriate yields and qualities is developed for each category by averaging characteristics of specific crude oil streams that fall into each category. While the domestic and foreign categories are the same, the composites for each type may differ, because different crude oil streams make up the composites.

Natural Gas Plants

The outputs of natural gas processing plants—ethane, propane, butane, isobutane, and natural gasoline—are modeled in the PMM. These products move directly into the market to meet demand or are inputs to the refinery.

Refinery Processes

Not every refinery processing unit is represented in PMM. The refinery processes represented were chosen because they have the most significant impact on production. The following distinct processes are represented:

Atmospheric distillation, vacuum distillation

Delayed coker

Fluid coker—includes flexicoking mode

Fluid catalytic cracker (FCC)—includes distillate, vacuum gas oil, coker gas oil, atmospheric residual, unallowable feeds; conversion ranges 65 to 85 percent; ZSM catalyst mode, low severity mode

Gas oil hydrocracker

Residuum hydrocracker

Naphtha hydrotreater

Distillate desulfurization

FCC feed hydrofiner

Residuum desulfurizer

Lube and wax units

Middle distillate deep hydrotreater

Solvent deasphalting

Catalytic reforming—separate units for semi-regenerative high-pressure, low-pressure cyclic; severity range as appropriate to the reactor; allow light straight run through heavy naphtha virgin streams, heavy naphthas from FCC, coker, and hydrocracker operations; allow new highly active catalyst operation

Naphtha splitter

FCC gasoline fractionation

C2-C5 dehydrogenation

Butane splitter

Butane isomerization

Isomerization for pentanes, hexanes

Butylene isomerization

Alkylation

Aromatics recovery

MTBE, ETBE, and TAME production (captive and merchant)

Gas processing

Hydrogen generation

Steam generation

Power generation

Cogeneration

Sulfur plant

Fuel mixer

Methanol production

ETBE=Ethyl tertiary butyl ether. MTBE=Methyl tertiary butyl ether. TAME=Tertiary amyl methyl ether.

End-Use Markups

The linear programming portion of the model provides unit prices of products sold in the refinery regions (refinery gate) and in the demand regions (wholesale). End-use markups are added to produce a retail price for each of the Census divisions. The markups are based on an average of historical markups, defined as the difference between the end-use prices by sector and the corresponding wholesale price for that product. The average is calculated using data from the past several years. Because of the lack of any discernible trend in the historical end-use markups, the markups remain fixed over the forecast period.

State and Federal taxes are also added to transportation fuel prices to determine final end-use prices. Recent tax trend analysis indicated that State taxes increase at the rate of inflation, while Federal taxes do not. In the PMM, therefore, State taxes are held constant in real terms throughout the forecast while Federal taxes are deflated at the rate of inflation.

Gasoline Types

The Clean Air Act Amendments of 1990 resulted in the production of a number of new blends of gasoline. In November 1992, a wintertime requirement for oxygenated gasoline containing a minimum of 2.7 percent oxygen by weight went into effect in the 39 worst carbon monoxide emitting areas. Since January 1995, gasoline sold year-round in the nine most severe ozone nonattainment areas has been "reformulated" according to U.S. Environmental Protection Agency specifications. A third type of gasoline, a higher oxygen reformulated blend, is sold in areas where the oxygenated and reformulated requirements overlap. In addition, California gasoline standards, which are more severe than the Federal reformulated standards, will become effective for that State in March 1996. Gasoline production is modeled within NEMS to account for these requirements. Additional product specifications can be accounted for as policy analysis scenarios.

Residential Demand Module

The residential demand module (RDM) forecasts fuel consumption in the residential sector for the nine Census divisions, three housing types, and numerous end-use, fuel-specific equipment types. Energy consumption is forecast for seven categories of fuel.

The structure of the RDM and its interactions with the NEMS system are shown in Figure 18. Important inputs and outputs are shown below. NEMS provides forecasts of residential energy prices, population, and housing starts, which are used by the RDM to develop forecasts of energy consumption for each of the seven fuels.

The RDM develops fuel consumption forecasts by first adjusting the previous year's housing stocks, adding new construction (housing starts) and subtracting retirements from the stock. Equipment choices are then simulated for new construction as well as for the replacement of equipment that has reached the end of its useful service life. In addition to modeling the stocks of energy-consuming equipment, the RDM also models the integrity of housing shells. Shell efficiencies for existing housing improve in response to increases in real energy prices, and shells for new construction improve from year to year, based on current building trends.

Next, the module's forecast of the characteristics of the residential housing and equipment stocks is used to forecast the intensity of use for the various types of equipment and the resulting energy consumption. Energy consumption for each end use is based on energy intensity estimates developed from EIA's 1993 Residential Energy Consumption Survey (RECS). These base energy intensities are modified for changes in equipment and shell efficiencies, prices, square footage, and weather. Once the modifications are made, total energy use is computed across end uses and housing types and then summed by fuel for each Census division. The detail carried in the RDM incorporates the effects on fuel consumption of regional demographic trends, housing trends, the replacement of appliances with more efficient units (from both standards and technological change), fuel switching, and housing shell retrofits.

Housing Stock Submodule

The base housing stock is derived from the 1993 RECS for three dwelling types: single-family, multifamily, and mobile homes. Each element of the base stock is retired on the basis of a constant rate of decay, which varies by dwelling type. The surviving stocks are supplemented by housing starts, which are provided through the NEMS macroeconomic activity module. Any housing added after the base year is tracked and retired as a separate vintage.

Appliance Stock Submodule

The base appliance stock is based on the 1993 RECS. Additions to the base stock are tracked separately for existing stocks of residential housing and for new construction. As houses decay from the existing stock, the associated appliances are removed from the appliance stock as well. A retirement function is used to retire equipment in housing that survives from one year to the next. As appliances are removed from the stock, they are replaced by new appliances with higher efficiencies. Appliances added through new construction are handled similarly. Appliance stocks are maintained by fuel, end use, and technology as follows:

Space heating equipment: electric furnace, electric air-source heat pump, natural gas furnace, natural gas other, kerosene furnace, liquefied petroleum gas, distillate furnace, distillate other, wood, ground-source heat pumps, natural gas heat pumps.

Space cooling equipment: electric room air conditioner, central air conditioner, electric air-source heat pump, ground-source heat pump, natural gas heat pump.

Water heaters: solar, natural gas, electric, oil, liquefied petroleum gas.

Refrigerators: 18 cubic foot top-mounted freezer, 25 cubic foot side-by-side with through-the-door features.

Freezers: chest - manual defrost, upright - manual defrost.

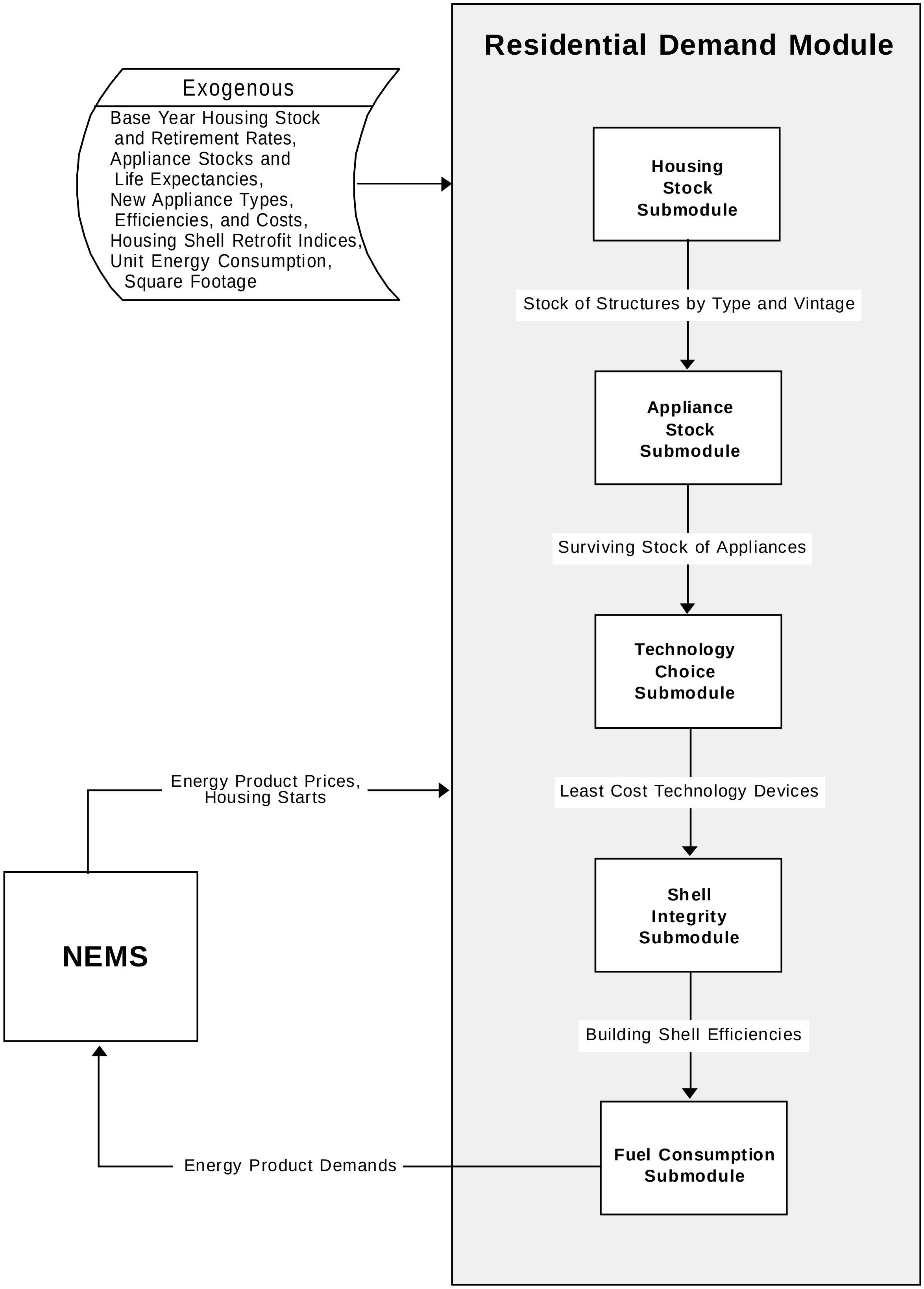
Lighting: incandescent, compact fluorescent, mercury vapor.

Clothes Dryers: natural gas, electric.

Cooking: natural gas, electric, liquefied petroleum gas.

Important RDM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Energy product demand Changes in housing and appliance stocks	Energy product prices Housing starts Population	Current housing stocks, retirement rates Current appliance stocks/life expectancy New appliance types, efficiencies, costs Housing shell retrofit indices, square footage Unit energy consumptions Square footage

Figure 18. Residential Demand Module Structure



Technology Choice Submodule

Fuel-specific equipment choices are made for both new construction and replacement purchases. For new construction, space heating equipment is chosen based on relative life cycle costs for all competing technologies. Base year heating system shares for new construction (1994) are provided by Census Bureau survey data for new construction. Once new home heating system shares are established, the fuel choices for other services, such as water heating and cooking, are determined based on the fuel chosen for space heating. For both replacement equipment and new construction, each equipment choice requires selecting from several efficiency levels that represent the range of efficiencies projected to be available to consumers at the time the choice is being made. At the low end of the efficiency range, base year efficiencies are adjusted to meet the minimum required standards. Efficiency choices are made on the basis of a comparison of relative initial capital and first-year operating costs.

Shell Integrity Submodule

Shell integrity is also tracked separately for the two housing vintages. Existing shells are assumed to respond to increases in real energy prices by becoming more efficient. New shell efficiencies are projected to increase, based on recent trends in shell efficiency. All shell efficiencies are subject to a maximum shell efficiency based on studies of currently available residential construction methods.

Fuel Consumption Submodule

The fuel consumption submodule modifies base year energy consumption intensities in each forecast year. Energy consumption for each end use is based on energy intensity estimates developed from the 1993 RECS. The base energy intensities are modified for five effects: (1) increases in efficiency, based on a comparison of the projected appliance stock serving this end use relative to the base year stock, (2) changes in shell integrity for space heating and cooling end uses, (3) changes in real fuel prices, (4) changes in square footage, and (5) changes in weather relative to the base year. Once these modifications are made, total energy use is computed across end uses and housing types and then summed by fuel for each Census division.

Commercial Demand Module

The commercial demand module (CDM) forecasts the consumption of commercial sector fuels and electricity by building types and nonbuilding uses of energy and by category of end use, subject to delivered prices of energy, the availability of renewable sources of energy, and macroeconomic variables representing gross domestic product, employment, interest rates, and floorspace construction. The CDM structure is shown in Figure 19. Important CDM inputs and outputs are shown below.

The commercial sector encompasses business establishments that are not engaged in industrial or transportation activities. Commercial sector energy is consumed mainly in buildings. (A small amount of commercial energy consumption—from uses such as street lights—is not attributable to buildings.) Energy consumed in commercial buildings is the sum of energy required to provide specific energy services using selected technologies. The model structure carries out a sequence of four basic steps, as shown in Figure 19. The first step is to forecast commercial sector floorspace. The second step is to forecast the energy services (space heating, lighting, etc.) required by that building space. The third step is to select specific technologies (natural gas furnaces, fluorescent lights, etc.) to meet the demand for energy services. The last step is to determine how much energy will be consumed by the equipment chosen to meet the demand for energy services. Building forecasts and equipment choices made in previous time periods determine the floorspace and equipment in place in future time periods.

The technologies and equipments selected to satisfy commercial service demand are chosen on the basis of a mixture of economic rationale (minimizing life cycle costs) and observed behavior (for example, replacing equipment that is returned with equipment using the same technology). The demand for energy is derived from the demand for end-use services. For example, the demand for energy for lighting is derived from the demand for lighting measured in lumens.

Floorspace Submodule

The pattern of energy consumption in the commercial sector depends on the number and type of buildings that make up the sector, regional differences in climate and building construction practices, and the energy-consuming equipment in the buildings. The first step is to forecast building construction and retirements by type of building and location. In this module, both demographic and economic variables are used to estimate growth in floorspace for the following 11 building types:

- Assembly
- Education
- Food sales
- Food services
- Health care
- Lodging
- Office-large
- Office-small
- Mercantile and service
- Warehouse
- Other.

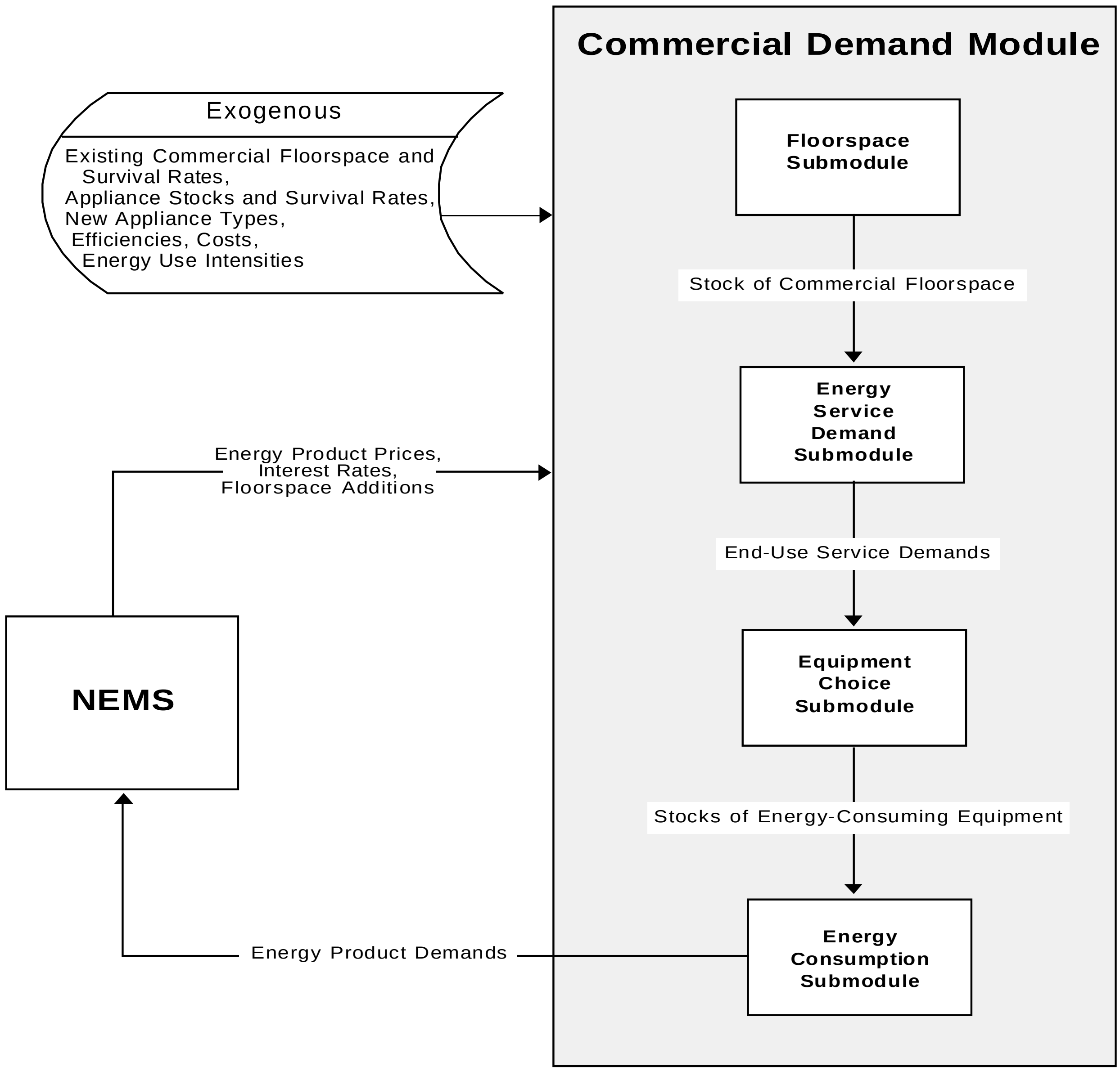
Energy Service Demand Submodule

Given the building inventory, the demand for energy-consuming services is forecast within the buildings. Consumers do not demand energy *per se*, but the services that energy provides. (Lighting is a good example of this concept. It is measured in units—lumens—that reflect consumers' perception of the level of service received.) The module specifically tracks the following nine services:

- Heating
- Cooling
- Ventilation
- Water heating
- Lighting
- Cooking
- Office equipment, personal computer (PC) and non-PC
- Refrigeration
- Other.

Important CDM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Energy product demands Changes in floorspace and appliance stocks	Energy product prices Interest rates Floorspace additions	Existing commercial floorspace Floorspace survival rates Appliance stocks and survival rates New appliance types, efficiencies, costs Energy use intensities

Figure 19. Commercial Demand Module Structure



Different building types require services at different levels. A hospital must have more light than a warehouse. An office building in the Northeast requires more heating than one in the South. Total service demand for any service depends on the number, size, type, and location of buildings.

In each forecast year, some equipment wears out in existing floorspace, leaving a gap between the energy services demanded and the equipment available to meet the demand. The efficiency of the equipment chosen to replace worn-out equipment is reflected in the average efficiency of the equipment stock. Similarly, the efficiency of equipment chosen to meet services in new floorspace is reflected in the average efficiency of the equipment stock.

Consumers may increase or decrease their level of use of a service in response to a change in energy prices. Accordingly, service demand forecasts are adjusted using short-term (constant) price elasticities of demand as appropriate in response to real short-term changes in energy prices. However, if the price of energy is constant from one year to the next, there is no effect on service demand.

Equipment Choice Submodule

Given the level of energy service demanded, the types of equipment and technologies that consumers purchase to satisfy the demand are projected. Consumers buy energy-using equipment to meet three types of service demand:

- Service demand in newly constructed buildings (buildings constructed in the current year)
- Service demand formerly met by retiring equipment (equipment that is at the end of its useful life and must be replaced)
- Service demand formerly met by equipment at the end of its economic life (equipment with a remaining useful life that is nevertheless retired on economic grounds).

The module is designed to allow the use of several possible assumptions about consumer behavior. The choices of consumer behavior assumptions are:

- Buy equipment with the minimum life-cycle cost across all fuels and technologies
- Buy equipment that uses the same fuel as existing and retiring equipment but minimizes costs under that constraint
- Buy (or keep) the same technology (and fuel) as the existing and retiring equipment but minimize costs under that constraint.

These behavior rules are designed to represent empirically the range of economic factors that influence consumers' decisions. Consumers who minimize life-cycle cost across all fuels and technologies are the most sensitive to energy price changes. The price sensitivity of the model depends on the share of consumers using each behavior rule. The share of consumers using each rule depends on the building type, type of service provided, and type of demand decision being considered. For example, the model run for *Annual Energy Outlook 1996* assumes that 40 percent of the consumers replacing space heating equipment in health care facilities will purchase equipment which uses the same fuel as the retiring equipment.

The module is designed to choose among a discrete set of technologies that are exogenously characterized by commercial availability, capital costs, operating and maintenance costs, efficiencies, and lifetime. The menu of equipment depends on technological innovation, market development, and policy intervention. The design can accommodate a changing menu of technology choices, recognizing that changes in energy prices and consumer demand may significantly change the set of relevant technologies the model user wants to consider. Vintages or versions with distinct properties may be specified for each type of technology. An example of two different vintages would be a natural gas furnace with a specific efficiency available in 1995 and a natural gas furnace with a higher efficiency available at a higher cost. At present, more than 1,000 technological choices are included for seven of the nine service demand categories, broken out by region and vintage, as follows:

Heating: electric air heat pump, electric baseboard, electric boiler, electric ground-source heat pump, natural gas boiler, natural gas furnace, natural gas heat pump, oil boiler, oil furnace.

Cooling: electric centrifugal chiller, electric reciprocating chiller, electric air heat pump, electric ground-source heat pump, window unit electric, natural gas air heat pump, natural gas engine rooftop, natural gas engine driven chiller, natural gas two-stage absorption chiller.

Water Heating: electric heat pump, electric resistance, natural gas, oil, high-efficiency electric heat pump, high-efficiency electric resistance, high-efficiency tankless electric, high-efficiency tankless natural gas, high-efficiency tankless oil, tankless electric, tankless natural gas, tankless oil.

Ventilation: constant air volume desiccant, constant air volume refrigeration, high-efficiency desiccant, high-efficiency variable air volume, variable air volume.

Cooking: electric convection oven, electric deck oven, electric fryer, electric griddle - standard, electric other, electric range - standard, natural gas deck oven, natural gas fryer - standard, natural gas griddle - standard, natural gas infrared fryer, natural gas infrared griddle, natural gas other, natural gas range - standard, natural gas range - power burn, high-efficiency electric fryer.

Lighting: compact fluorescent, fluorescent, fluorescent high efficiency, incandescent, incandescent high efficiency, mercury vapor, metal halide, sodium high pressure.

Refrigeration: medium temperature open case, medium temperature glass door, medium temperature strip curtain, medium temperature non-CFC 2-stage R22, medium temperature with mechanical subcooling, low temperature open case, low temperature with glass door, low temperature with high efficiency motor, low temperature with time control, low temperature with non-CFC 2-stage R22, very low temperature open case, very low temperature glass door, very low temperature with high efficiency motor, very low temperature with hot gas defrost, very low temperature non-CFC 2-stage R-22.

The minor services (office equipment and "other" services) are forecast using exogenous equipment efficiency and market penetration trends.

Energy Consumption Submodule

Given the choice of equipment to satisfy service demands, the total amount of energy consumed is projected. To calculate energy consumption, the equipment share for each fuel and its corresponding efficiency is applied to service demand.

Transportation Demand Module

The transportation demand module (TRAN) forecasts the consumption of transportation sector fuels by transportation mode, including the use of renewables and alternative fuels, subject to delivered prices of energy fuels and macroeconomic variables, including disposable personal income, gross domestic product, level of imports and exports, industrial output, new car and light truck sales, and population. The structure of the module is shown in Figure 20. Important inputs and outputs are shown below.

Alternative-fuel shares are projected on the basis of a multinomial logit vehicle attribute model, subject to State and Federal government mandates. NEMS projections of future fuel prices influence the fuel efficiency, vehicle-miles traveled, and alternative-fuel vehicle market penetration for the current fleet of vehicles. Fleet vehicle characteristics and alternative fuel penetration can be set by the user to conduct an analysis of specific policy requirements.

Fuel Economy Submodule

This submodule projects new light-duty vehicle fuel efficiency by vehicle size class as a function of energy prices and income-related variables. In general, higher fuel prices lead to higher fuel efficiency estimates within each size class, a shift to a more fuel-efficient size class mix, and an increase in the rate at which alternative-fuel vehicles enter the marketplace. For purposes of policy analysis, the user can specify both fuel efficiency by size class and size class shares exogenously.

Regional Sales Submodule

This submodule is a simple accounting mechanism that uses exogenous estimates of new car and light truck sales and the results of the fuel economy submodule to produce estimates of regional sales and characteristics of light-duty vehicles, which are subsequently passed to the alternative-fuel vehicle and the light-duty vehicle stock submodules.

Alternative-Fuel Vehicle Submodule

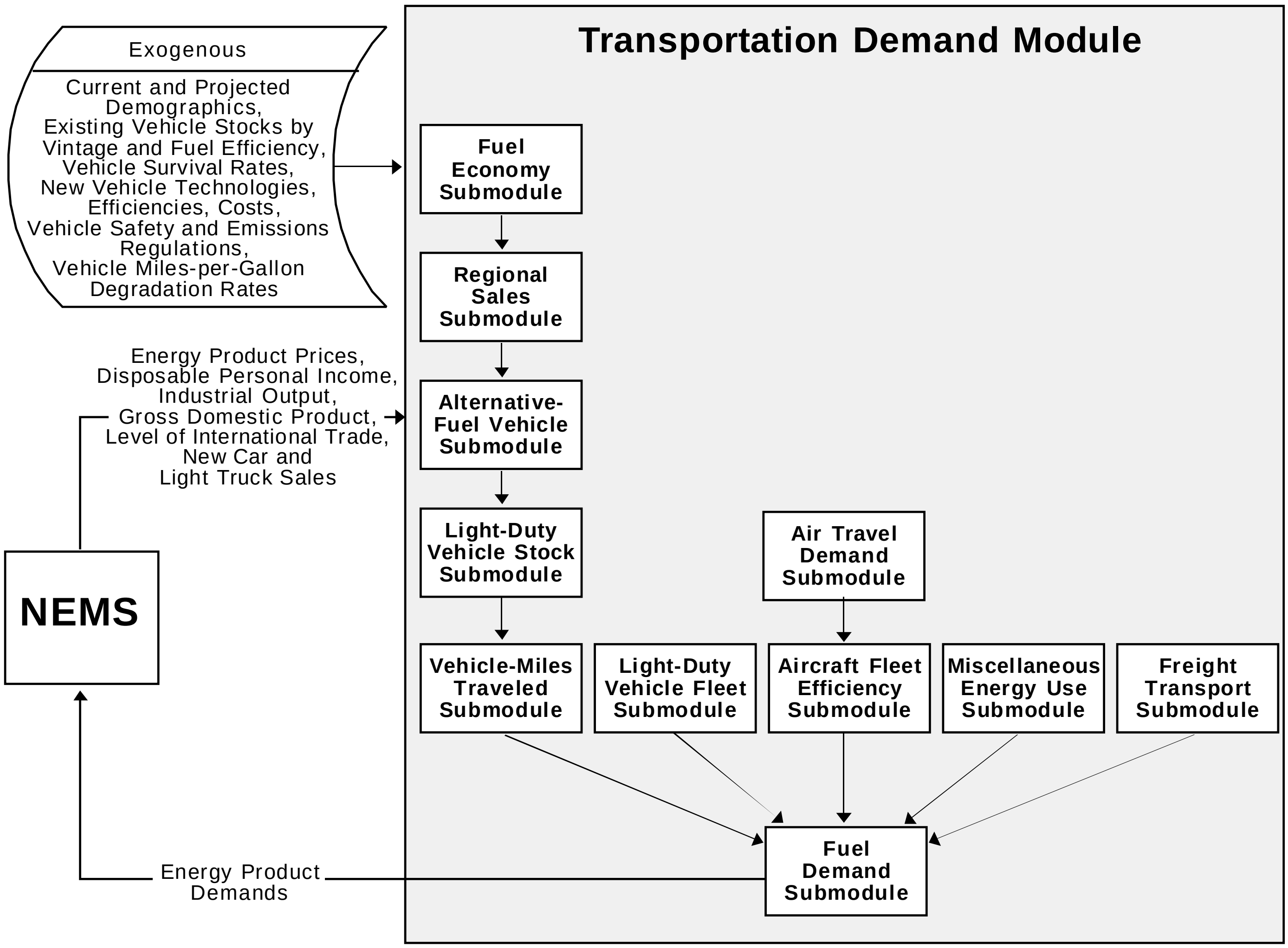
This submodule projects the sales shares of alternative-fuel technologies as a function of time, technology attributes, costs, and fuel prices. Both conventional and new technology vehicles are considered. The alternative-fuel vehicle submodule receives regional new car and light truck sales by size class from the regional sales submodule.

The forecast of vehicle sales by technology requires a three-stage nested decision process. The first stage consists of endogenously calculating the sales shares between conventional and total alternative-fuel vehicles on a regional level, based on the following regional factors: fuel operating costs per mile (fuel price divided by fuel efficiency), vehicle price, range, emission levels, fuel availability, commercial availability, and regulatory constraints.

Once the level of total alternative-fuel vehicles per region has been calculated, the second stage estimates shares among the alternative-fuel vehicle technologies within each region, based on the same regional factors and methodology used in the prior step to calculate the shares of conventional and total alternative-fuel vehicle sales. Both the share between conventional and alternative-fuel sales and the share among the alternative-fuel vehicle technologies have two alternative structures, one for exogenously specifying the shares based on off-line analysis and another that endogenously forecasts the shares. The third stage subdivides electric vehicle sales into individual electric vehicle technologies.

Important TRAN Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Fuel demand by mode Sales, stocks and characteristics of vehicle types by size class Vehicle-miles traveled Fuel efficiencies by technology type Alternative-fuel vehicle sales by technology type Light-duty commercial fleet vehicle characteristics	Energy product prices Gross domestic product Disposable personal income Industrial output New car and light truck sales International trade	Current and projected demographics Existing vehicle stocks by vintage and fuel economy Vehicle survival rates New vehicle technologies and efficiencies, relative to conventional vehicles Vehicle prices, fuel availability, and commercial availability Vehicle safety and emissions regulations Vehicle miles-per-gallon degradation rates

Figure 20. Transportation Demand Module Structure



TRAN includes the following alternative-fuel technologies:

Methanol flex-fueled
Methanol neat (85 percent methanol)
Ethanol flex-fueled
Ethanol neat (85 percent ethanol)
Compressed natural gas (CNG)
CNG Bi-Fuel
Liquefied petroleum gas (LPG)
LPG Bi-Fuel
Electric
Electric hybrid small internal combustion engine
Gas turbine gasoline
Gas turbine CNG
Fuel cell methanol
Fuel cell liquid hydrogen

Light-Duty Vehicle Stock Submodule

This submodule specifies the inventory of light-duty vehicles from year to year. The survival rates and new vehicle sales of different vintages and classes can be set to reflect alternative policy scenarios that target specific vintages or size classes. The fleet of vehicles and their fuel efficiency characteristics are important to the translation of transportation services demand into fuel demand.

The level of detail maintains ten vintage classifications and six passenger car and six light truck size classes corresponding to U.S. Environmental Protection Agency interior volume classifications, as follows:

Cars:
- Mini-compact - less than 85 cubic feet
- Subcompact - between 85 and 99 cubic feet
- Compact - between 100 and 109 cubic feet
- Mid-size - between 110 and 119 cubic feet
- Large - 120 or more cubic feet, including all station wagons (small, mid-size, and large)
- Two-seater - designed to seat two adults

Trucks:
- Passenger vans
- Cargo vans
- Small pickups - trucks with gross vehicle weight rating (GVWR) less than 4,500 pounds
- Large pickups - trucks with GVWR 4,500 to 8,500 pounds
- Small utility
- Large utility

Vehicle-Miles Traveled Submodule

This submodule projects travel demand for automobiles and light trucks. The estimates are based on the fuel cost of driving, per capita disposable personal income, an index that reflects the aging of the population, and an adjustment for female-to-male driving ratios.

Light-Duty Vehicle Fleet Submodule

This submodule generates estimates of the stock of cars and trucks used in business, government, and utility fleets. It also estimates travel demand, fuel efficiency, and energy consumption for the fleet vehicles prior to their transition to the private sector at predetermined vintages.

Air Travel Demand Submodule

This submodule estimates the demand for both passenger and freight air travel. Historical data on passenger travel are disaggregated between business and personal travel, while freight travel is disaggregated by dedicated freight aircraft and air freight carried in the lower hull ("belly") of commercial passenger aircraft. In each of the four market segments, the demand for air travel is estimated through regression analysis as a function of the cost of air travel (including fuel costs) and economic growth.

Aircraft Fleet Efficiency Submodule

This submodule projects commercial aircraft stocks to provide estimates of average aircraft fuel efficiency (seat-miles per gallon) by size class as a function of jet fuel prices (which affect technology choices) and economic growth levels (which affect the age distribution of aircraft).

Freight Transport Submodule

This submodule translates NEMS estimates of industrial production into ton-miles traveled requirements for truck, rail, and ship travel, then into fuel consumption by mode of freight travel. NEMS industrial production forecasts indicate value added by industry. Energy efficiency estimates of freight travel are structured to evaluate the potential of both technology trends and efficiency improvements related to energy prices.

Miscellaneous Energy Use Submodule

This submodule projects the use of energy in military operations, mass transit vehicles, recreational boats, and automotive lubricants, based on endogenous variables within NEMS (e.g., vehicle fuel efficiencies) and exogenous variables (e.g., the military budget).

Industrial Demand Module

The industrial demand module (IDM) forecasts the consumption of fuels and electricity for heat and power and for feedstocks and raw materials at a process or end-use level for the energy-intensive industries, including the direct use of renewable energy, subject to delivered prices of energy and macroeconomic variables representing the value of output for each industry. The module includes industrial cogeneration of electricity that is either used in the industrial sector or sold to electric utilities. The IDM structure is shown in Figure 21. Important inputs and outputs are given below.

Industrial energy demand is projected as a combination of "bottom up" characterizations of the energy-using technology and "top down" econometric estimates of behavior. The influence of energy prices on industrial energy consumption is modeled in terms of the efficiency of use of existing capital, the efficiency of new capital acquisitions, and the mix of fuels utilized, given existing capital stocks. Energy conservation from technological change is represented over time by trend-based "technology possibility curves." These curves represent the aggregate efficiency of all new technologies that are likely to penetrate the future markets as well as the aggregate improvement in efficiency of 1991 technology. Energy product demands are found independently for each sector.

The IDM incorporates three major industry categories: energy-intensive manufacturing industries, non-energy-intensive manufacturing industries, and non-manufacturing industries. The level and type of modeling and the attention to detail can be different for each. Manufacturing disaggregation is at the 2-digit Standard Industrial Classification (SIC) level, with some further disaggregation of more energy-intensive or large energy-consuming industries. Industries treated in more detail include food, paper, chemicals, petroleum refining, stone/clay/glass, and primary metals.

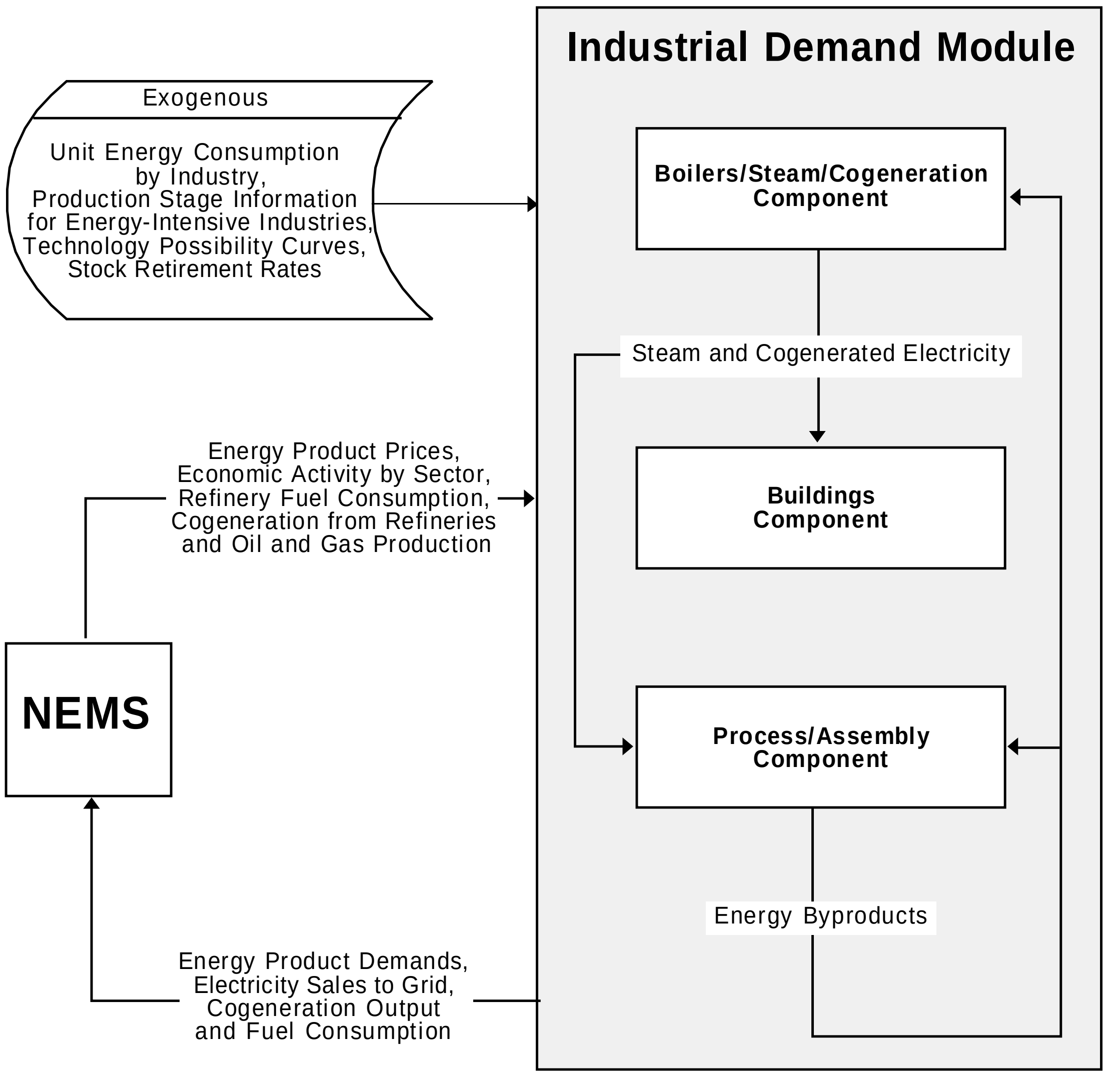
Each industry is modeled (where appropriate) as three separate but interrelated components: buildings (BLD), boilers/steam/cogeneration (BSC), and process/assembly (PA) activities. Buildings are estimated to account for 3 percent of energy consumption in manufacturing industries (in nonmanufacturing industries, building energy consumption is assumed to be negligible). Consequently, the IDM uses a simple modeling approach for the BLD component. Energy consumption in industrial buildings is assumed to grow at the same rate as employment in that industry. The BSC component consumes energy to meet the steam demands from the other two components and to provide internally generated electricity to the BLD and PA components. The boiler component consumes fossil fuels to produce steam, which is passed to the PA component. Parameter estimates for the cogeneration component are based on regression from a panel of pooled time-series and cross-sectional data. The IDM models cogeneration based on steam demand from the BLD and the PA components and represents planned and unplanned "traditional" cogeneration units based on Form EI-867, "Annual Nonutility Power Producer Report," estimates. The "nontraditional" cogeneration units are not represented since these units are mainly grid-serving, electricity-price-driven entities.

The PA component accounts for the largest share of direct energy consumption for heat and power, 54 percent. For the seven most energy-intensive industries, process flows are modeled using engineering concepts. The production process is decomposed into the major steps, and the energy relationships among the steps are specified. The energy intensities of the process steps vary over time, both for existing technology and for technologies expected to be adopted in the future. In the IDM, this variation is based on engineering judgment and is reflected in the parameters of technology possibility curves, which show the (declining) energy intensity of existing and new capital relative to the 1991 stock.

The model uses a vintaged capital stock accounting framework that models energy use in new additions to the stock and in the existing stock. This capital stock is represented as the aggregate vintage of all plants built within an industry and does not imply the inclusion of specific technologies or capital equipment.

Important IDM Outputs	Important Inputs from NEMS	Important Exogenous Inputs
Energy product demand Electricity sales to grid Cogeneration output and fuel consumption	Energy product prices Economic output by industry Refinery fuel consumption Cogeneration from refineries and oil and gas production	Production stages in energy-intensive industries Technology possibility curves Unit energy consumption Stock retirement rates

Figure 21. Industrial Demand Module Structure



Currently, the capital stock is grouped into three vintages: old, middle, and new. The old vintage consists of capital in production prior to 1991, which is assumed to retire at a fixed rate each year. Middle-vintage capital is that added after 1990, excluding the year of the forecast. New production capacity is built in the forecast years when the capacity of the existing stock of capital in the IDM cannot produce the output forecasted by the NEMS regional subcomponent of the macroeconomic activity module. Capital additions during the forecast horizon are retired in subsequent years at the same rate as the pre1990 capital stock.

The energy-intensive and/or large energy-consuming industries are modeled with a structure that explicitly describes the major process flows or "stages of production" in the industry (some industries have major consuming uses). The concepts of aggregate production functions and cost functions are used implicitly in modeling factor shares, primarily energy, at each process level. The initial algorithms do this implicitly, but a structure is provided so that the algorithms can be enhanced, with relative factor shares being related to relative factor prices.

Technology penetration at the level of major processes in each industry is based on a technology penetration curve relationship. A second relationship provides additional energy conservation resulting from changes in absolute and relative energy prices. Elasticities, constraints, and/or technical possibilities vary according to the vintage. Major process choices (where applicable) are determined by industry production, specific process flows, and exogenous assumptions.

The model achieves fuel switching by application of a logit function methodology for estimating fuel shares in the boilers/steam/cogeneration component. Additional fuel switching capability takes place within the non-energy-intensive manufacturing sector through the application of the translog function methodology for estimating fuel shares.

Recycling, waste products, and byproduct consumption are modelled using parameters based on off-line analysis and assumptions about the manufacturing processes or technologies applied within industry. These analyses and assumptions are mainly based upon environmental regulations such as government requirements about the share of recycled paper used in offices. The model also accounts for trends within industry toward the production of more specialized products such as specialized steel which can be produced using scrap material versus raw iron ore.

BIBLIOGRAPHY

The National Energy Modeling System is documented in a series of model documentation reports, available by contacting the National Energy Information Center (202/586-8800).

Energy Information Administration, *National Energy Modeling System Integrating Module Documentation Report*, DOE/EIA-M057(95) (Washington, DC, May 1995).

Energy Information Administration, *Model Documentation Report: Macroeconomic Activity Module (MAM) of the National Energy Modeling System*, DOE/EIA-M065 (Washington, DC, February 1994).

Energy Information Administration, *Model Developer's Appendix to the Model Documentation Report: NEMS Macroeconomic Activity Module*, DOE/EIA-M065A(95) (Washington, DC, July 1994).

Energy Information Administration, *Documentation of the DRI Model of the U.S. Economy*, DOE/EIA-M061 (Washington, DC, December 1993).

Energy Information Administration, *NEMS International Energy Module, Model Documentation Report*, DOE/EIA-M071 (Washington, DC, April 1994).

Energy Information Administration, *EIA Model Documentation: World Oil Refining Logistics Demand Model, "World" Reference Manual*, DOE/EIA-M058 (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation Report: Residential Sector Demand Module of the National Energy Modeling System*, DOE/EIA-M067(95) (Washington, DC, March 1995).

Energy Information Administration, *Model Documentation Report: Commercial Sector Demand Module of the National Energy Modeling System*, DOE/EIA-M066(95) (Washington, DC, February 1995).

Energy Information Administration, *National Energy Modeling System Industrial Demand Module Documentation Report*, DOE/EIA-M064 (Washington, DC, January 1994).

Energy Information Administration, *Model Documentation Report: Transportation Sector Model of the National Energy Modeling System*, DOE/EIA-M070 (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation: Electricity Market Module, Load and Demand-Side Management Submodule. Volume 1: Model Description*, DOE/EIA-M068-A/1 (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation: Electricity Market Module, Load and Demand-Side Management Submodule. Volume 2: Model Code Listing*, DOE/EIA-M068-A/2 (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation: Electricity Market Module, Electricity Capacity Planning Submodule*, DOE/EIA-M068-B (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation: Electricity Market Module, Modifications to the Electricity Capacity Planning Submodule*, DOE/EIA-M068-B/1 (Washington, DC, April 1995).

Energy Information Administration, *Model Documentation: Electricity Market Module, Electricity Finance and Pricing Submodule*, DOE/EIA-M068-C (Washington, DC, March 1994).

Energy Information Administration, *Model Documentation: Electricity Market Module, Electricity Fuel Dispatch Submodule*, DOE/EIA-M068-D (Washington, DC, March 1994).

Energy Information Administration, *Documentation of the Electricity Market Module (EMM). Appendix: Model Developer's Report*, DOE/EIA-M068(95)Appx (Washington, DC, February 1995).

Energy Information Administration, *Documentation of the Oil and Gas Supply Module (OGSM)*, DOE/EIA-M063(95) (Washington, DC, October 1995).

Energy Information Administration, *Documentation of the Oil and Gas Supply Module (OGSM). Appendix: Model Developer's Report*, DOE/EIA-M063A(95) (Washington, DC, July 1994).

Energy Information Administration, *Model Documentation: Natural Gas Transmission and Distribution Model of the National Energy Modeling System. Volume 1*, DOE/EIA-M062/1(95) (Washington, DC, February 1995).

BIBLIOGRAPHY

Energy Information Administration, *Model Documentation: Natural Gas Transmission and Distribution Model (NGTDM) of the National Energy Modeling System. Volume 2: Model Developer's Report*, DOE/EIA-M062/2 (Washington, DC, January 1995).

Energy Information Administration, *EIA Model Documentation: Petroleum Market Model of the National Energy Modeling System*, DOE/EIA-M059(95) (Washington, DC, December 1994).

Energy Information Administration, *Documentation of the Petroleum Market Model (PMM). Appendix: Model Developer's Report*, DOE/EIA-M059/A (Washington, DC, December 1994).

Energy Information Administration, *Model Documentation: Coal Market Module of the National Energy Modeling System*, DOE/EIA-M060(95) (Washington, DC, March 1995).

Energy Information Administration, *Model Documentation: Renewable Fuels Module of the National Energy Modeling System*, DOE/EIA-M069(95) (Washington, DC, July 1995).

Energy Information Administration, *Model Documentation: Renewable Fuels Module of the National Energy Modeling System. Appendix: Model Performance*, DOE/EIA-M069/A (Washington, DC, September 1994).