Liquid Fuels Market Module of the National Energy Modeling System: Model Documentation 2025

August 2025

Independent Statistics and Analysis
U.S. Energy Information Administration

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Washington, DC 20585

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Acronyms and Abbreviations

AB32	California Assembly Bill 32, known as the Global Warming Solutions Act of 2006
ADU	atmospheric distillation unit
AEO	*Annual Energy Outlook*
AFPM	American Fuel and Petrochemical Manufacturers
API	American Petroleum Institute
ASTM	formerly known as the American Society for Testing and Materials
b	barrel
b/cd	barrels per calendar day
Btu	British thermal unit
CARB	California Air Resources Board
CCATS	Carbon Capture, Allocation, Transportation, and Sequestration Module
CD	census division
CHP	combined heat and power
Cn	Represents a hydrocarbon stream containing *n* atoms of carbon, in other words, C1 is methane, C2 is ethane, C3 is propane, C4 is butane, etc.
DOE	U.S. Department of Energy
E85	Gasoline blend of 51-83% ethanol and the rest conventional gasoline (The annual average of ethanol content in E85 is 74%, when factoring in cold-start need in winter)
EIA	U.S. Energy Information Administration
EISA2007	Energy Independence and Security Act of 2007
EPA	U.S. Environmental Protection Agency
FERC	U.S. Federal Energy Regulatory Commission
FOE	fuel oil equivalent
HGL	hydrocarbon gas liquids
HMM	Hydrogen Market Module
HSM	Hydrocarbon Supply Module
IEO	*International Energy Outlook*
IEM	International Energy Model
ISBL	inside the battery limit
kWh	kilowatthour
LCFS	Low Carbon Fuel Standard
LFMM	Liquid Fuels Market Module
LP	linear programming
LPG	liquefied petroleum gas
Mb/cd	thousand barrels per calendar day
MBtu	thousand British thermal units
MMb/cd	million barrels per calendar day
MMBtu	million British thermal units
MTBE	methyl tertiary butyl ether
MW	megawatts, electric generation capacity
MWh	megawatthour
NEMS	National Energy Modeling System
NGL	natural gas liquid
NGPL	natural gas plant liquid
NPC	National Petroleum Council
OVC	other variable costs

PADD	Petroleum Administration for Defense District
PCF	petrochemical feed
PMM	Petroleum Market Model
ppm	parts per million
PSA	*Petroleum Supply Annual*
RFG	reformulated gasoline
RFS	Renewable Fuels Standard
RVP	Reid vapor pressure
RYM	Refinery Yield Model (EIA)
SCF	standard cubic feet
SPR	Strategic Petroleum Reserve
STEO	*Short-Term Energy Outlook*
TRG	conventional gasoline
ULSD	ultra-low sulfur diesel

Update Information

This edition of the *Liquid Fuels Market Module (LFMM) of the National Energy Modeling System: Model Documentation 2025* reflects changes made to the module during the past two years and included in the *Annual Energy Outlook 2025*. These changes include:

- Modified penetration potential of E15 (motor gasoline blend containing up to 15% fuel ethanol) to be regionally defined as either low, medium, or high, where penetration begins slowly in 2019 and grows to a maximum of about 20%, 35%, and 55%, respectively, by 2050
- Revised Renewable Fuel Standard (RFS) levels for historical and near-term years on the U.S. Environmental Protection Agency's (EPA) June 2023 final renewable volume obligation (RVO).
- Added representation of Washington's Clean Fuel Standard
- Added representation for ethanol plant carbon capture retrofits to support the Carbon Capture, Allocation, Transportation, and Sequestration (CCATS) Module
- Modified refinery hydrogen representation where refinery hydrogen production (including on-site steam methane reformers) is now produced by the Hydrogen Market Module (HMM) and consumed as a feedstock demanded by LFMM
- Updated E85 infrastructure representation and availability curve, including new design for E85 availability curve
- Extended Clean Fuels Production tax credits through 2027 per legislation
- Added revenue for sale of distillers dried grain
- Updated regional mapping of seed oil supply curve data from Polysys (National Energy Modeling System Renewable Fuels Module) as feedstock option for biodiesel and renewable diesel
- Updated refinery and non-refinery existing and planned capacity data as well as refinery cogeneration data
- Updated renewable diesel, biodiesel, and ethanol capacity data as well as growth rates
- Updated data defining crude oil and petroleum product transportation network, transport costs, and transport capacity for both domestic and import/export links
- Updated data used to estimate state-mandated ultra-low sulfur heating oil
- Updated other historical data for prices and volumes
- Updated distribution markups and costs for gasoline, diesel, E85, and jet fuel
- Updated state and federal fuel taxes
- Updated fuel handling for refinery fuel units
- Updated mandated drawdown of U.S. Strategic Petroleum Reserve

Introduction

Purpose of this report

The purpose of this report is to define the objectives of the Liquid Fuels Market Module (LFMM), describe its basic approach, and provide details on how it works. This report is a reference document for model analysts and users. It is also a tool for model evaluation and improvement. Documentation of the model is in accordance with EIA's legal obligation to provide adequate documentation in support of its models (Public Law 94-385, section 57.b.2). An overview of the LFMM and its major assumptions is available in two related documents: *Annual Energy Outlook* and *Assumptions to the Annual Energy Outlook*. This volume documents the version of the LFMM used for the current *Annual Energy Outlook* (AEO) and supersedes all previous versions of the LFMM documentation.

Model summary

The LFMM models petroleum refining activities, the marketing of petroleum products to consumption regions, imports and exports of petroleum liquids, the distribution of natural gas liquids from natural gas processing plants, and the production of renewable fuels (including ethanol, biomass-based diesel, and cellulosic biofuels) and non-petroleum fossil fuels. The LFMM projects domestic petroleum product prices and movement of liquid fuel quantities for meeting petroleum product demands by supply source, fuel, and region. These liquid fuels include:

- Domestic, imported, and exported crude oil
- Domestic, imported, and exported petroleum products
- Alcohols, biomass-based diesel, and other biofuels
- Domestic natural gas plant liquids
- Unfinished oil imports and exports

In addition, the LFMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the census division (CD) level, while much of the liquid fuels production activity information is at the level of Petroleum Administration for Defense Districts (PADDs) and sub-PADDs.

Model archival citation

The LFMM is archived as part of the National Energy Modeling System (NEMS) for the current AEO.

Organization of this report

The remainder of this report is organized in the following chapters:

- Model Purpose
- Model Rationale
- Model Code Structure
- Appendices
  - A. Data and Outputs
  - B. Mathematical Description of Model
  - C. Bibliography
  - D. Model Abstract

- E. Data Quality
- F. Estimation Methodologies
- G. Historical Data Processing

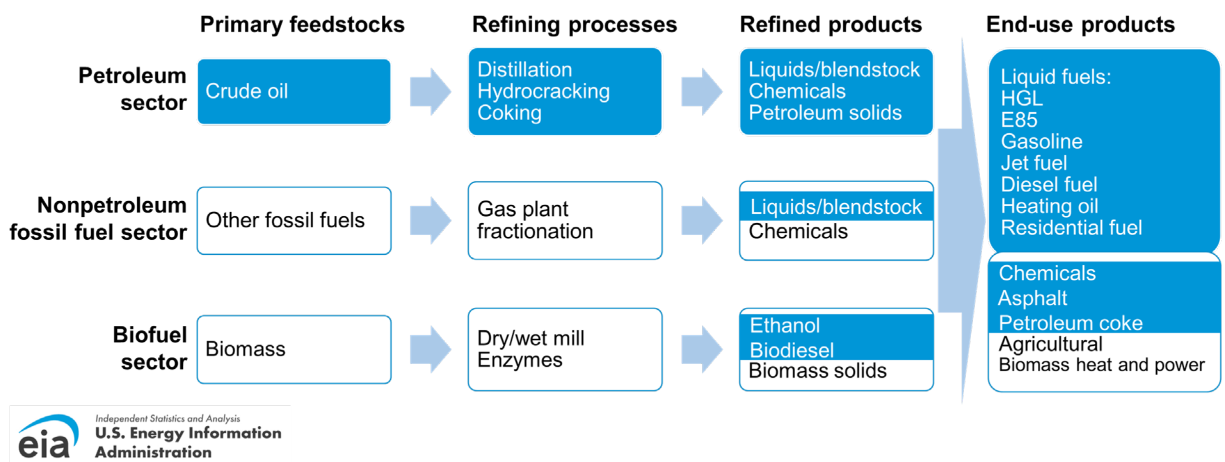
Model Purpose

Model objectives

The Liquid Fuels Market Module (LFMM) models production and marketing of liquid fuels, including petroleum products and non-petroleum liquid fuels. The purpose of the LFMM is to project liquid fuel prices, production activities, and movements of petroleum into and out of the United States and among domestic regions. In addition, the LFMM estimates capacity expansion and fuel consumption in the liquid fuels production industry. The LFMM is also used to analyze a wide variety of issues and policies related to petroleum fuels and non-petroleum liquid fuels in order to foster a better understanding of the liquid fuels industry and the effects of certain policies and regulations.

The production processes and physical flows represented in LFMM are shown in the figure below.

Figure 1. Liquid fuels production industry, with the Liquid Fuels Market Module highlighted in blue



Source: U.S. Energy Information Administration, Office of Energy Analysis
Note: E85 refers to a blend of up to 85% ethanol and 15% motor gasoline.

The LFMM simulates the operation of petroleum refineries and non-petroleum liquid fuels production plants in the United States. The module also has a simple representation of the international refinery market used to provide competing crude oil and petroleum product[1] import and export prices and quantities. The U.S. component includes the supply and transportation of crude oil to refineries, regional processing of these raw materials into petroleum products, and the distribution of petroleum products to meet regional demands. The U.S. component also represents the marketing and distribution of the fractionated natural gas liquids from natural gas processing plants and the processing and marketing of renewable fuel feedstock (corn, biomass, seed oils, fats, and greases) into alcohol and biomass-based diesel and naphtha liquid blends. The essential outputs of this model are domestic liquid fuels product prices, a petroleum supply and demand balance (including crude oil and petroleum product imports and exports), demands for refinery fuel use, and capacity expansion decisions.

[1] The International Energy Module (IEM) in NEMS provides price and quantity representation for foreign crude and product supplies and demands.

Inputs to the LFMM:

- Domestic petroleum product demands
- International petroleum product import/export curves and import/export links to LFMM regions
- Domestic crude oil production levels for 9 crude oil types, including average California crude oil
- International crude oil supply curves for 10 crude oil types, excluding California and including Canadian syncrude and dilbit, and import/export links to LFMM regions
- Costs of energy inputs such as natural gas, electricity, and coal
- Costs and available quantities of feedstocks (such as biomass, corn, etc.) used to produce blending components (such as ethanol and biodiesel)
- Yield coefficients for crude oil distillation and other processing units
- Existing and planned process unit capacities
- Investment costs for capacity expansion
- Capacities and tariffs for pipeline and other transportation modes for crude oil and petroleum products
- Product specifications
- Policy requirements (including RFS, LCFS, AB32, etc.)

From these inputs, the LFMM produces:

- A slate of domestic prices for petroleum products
- Regional domestic crude oil prices
- The quantity of crude oil processed at domestic refineries
- Imports and exports of crude oil and petroleum products
- Estimates of other refinery inputs and processing gain
- Domestic capacity expansion for petroleum refineries and biorefineries and refinery utilization
- Biofuels production levels
- Refinery fuel consumption, including electricity, natural gas, still gas, and catalyst coke

The LFMM represents liquid fuels production, distribution and marketing operations needed to support domestic petroleum and biofuels demand modeling efforts for the Annual Energy Outlook (AEO). The model also analyzes a wide variety of related issues. The LFMM is able to project the impacts on refinery operations and on the marginal costs of refined products associated with changes in:

- Demands for various kinds of petroleum products
- Crude oil prices and domestic production levels
- Refinery processing unit capacities
- Petroleum product specifications
- Energy policies and regulations
- Taxes, tariffs, and subsidies

Relationship to other models

The LFMM represents the liquid fuels production and marketing sector within the National Energy Modeling System (NEMS). The LFMM projects petroleum product prices, crude oil and petroleum product import and export levels, and supplies and production of alternative fuels. These projections are generated as part of a NEMS supply/demand/price equilibrium solution. The LFMM does not examine inventories or inventory changes between projection years.

Several other models in NEMS provide inputs to the LFMM:

- The Residential Demand Module (RDM), Commercial Demand Module (CDM), Industrial Demand Module (IDM), Transportation Demand Module (TDM), and Electricity Market Module (EMM) provide demands for petroleum products. The demands include motor gasoline, E85, jet fuel, kerosene, heating oil, ultra-low sulfur diesel, CARB gasoline and diesel, low- and high-sulfur residual fuel, liquefied petroleum gases (LPG), petrochemical feedstocks, petroleum coke, and other petroleum products (such as lubes and asphalt).
- The International Energy Module (IEM) provides the benchmark crude oil price. The IEM provides a benchmark crude oil supply curve for Brent (light-sweet) crude oil, as well as for nine other crude oil types. Regional prices for these crude oil types are computed in the LFMM based on the import and export decision levels for each crude oil type.
- The Hydrocarbon Supply Module (HSM) provides domestic crude oil production levels. The crude oil is categorized into the same types represented for the import supply curves (excluding Canadian dilbit and syncrude), plus an average California crude oil.
- Natural gas liquids, which are among the non-crude oil inputs to refineries, are also estimated by HSM from domestic natural gas production levels and characteristics.
- Coal supply information (prices and quantities on supply curves, coal type, transportation network, emissions, and consumption for electricity generation and other needs), along with coal demands by other sectors (for example, an electric utility), are provided by the Coal Market Module (CMM).
- The Natural Gas Market Module (NGMM) provides natural gas prices, and the Electricity Market Module (EMM) provides electricity prices. The LFMM estimates the refinery consumption of these energy sources.
- The Macroeconomic Activity Module (MAM) provides certain macroeconomic parameters. The Baa average corporate bond rate (reflects a low-risk investment) is used for the cost of debt calculation, and the 10-year Treasury note rate is used for the cost of equity calculation. Both rates are used in estimating the capital-related financial charges for refinery and liquid fuels process unit investments. Discount rates (GDP) are also provided by the MAM.
- The Renewable Fuels Module (RFM) provides corn, cellulosic, and soy bean oil feedstock prices and quantities.
- The TDM provides logit function and other parameters used to estimate the ratio of E85 to motor gasoline usage for flex fuel vehicles (FFV).
- The Hydrogen Market Module (HMM) provides hydrogen supply prices.

- The Carbon Capture, Allocation, Transportation, and Sequestration Module (CCATS) provides prices for captured and sequestered carbon from ethanol plants with carbon capture and sequestration (CCS).

The LFMM also provides information to other NEMS modules:

- Passes prices of petroleum products to the RDM, CDM, IDM, TDM, and EMM to estimate end-use demands for the various fuels.
- Passes regional domestic crude oil prices to the HSM.
- Provides supply balance quantities, including crude oil refinery inputs, non-crude oil refinery inputs, and processing gain, for reporting purposes.
- Determines capacity expansion and utilization rates at petroleum refinery and biorefinery plants mainly for reporting purposes.
- Passes fuel consumption at refineries to the IDM for inclusion in the industrial sector totals. In addition, refinery combined-heat-and-power (CHP) capacity and generation levels are sent to the IDM and EMM.
- Sends cellulosic biomass consumption to the RFM.
- Provides hydrogen consumption volumes to the HMM.
- Determines builds of CCS facilities to existing ethanol plants and passes this to CCATS.

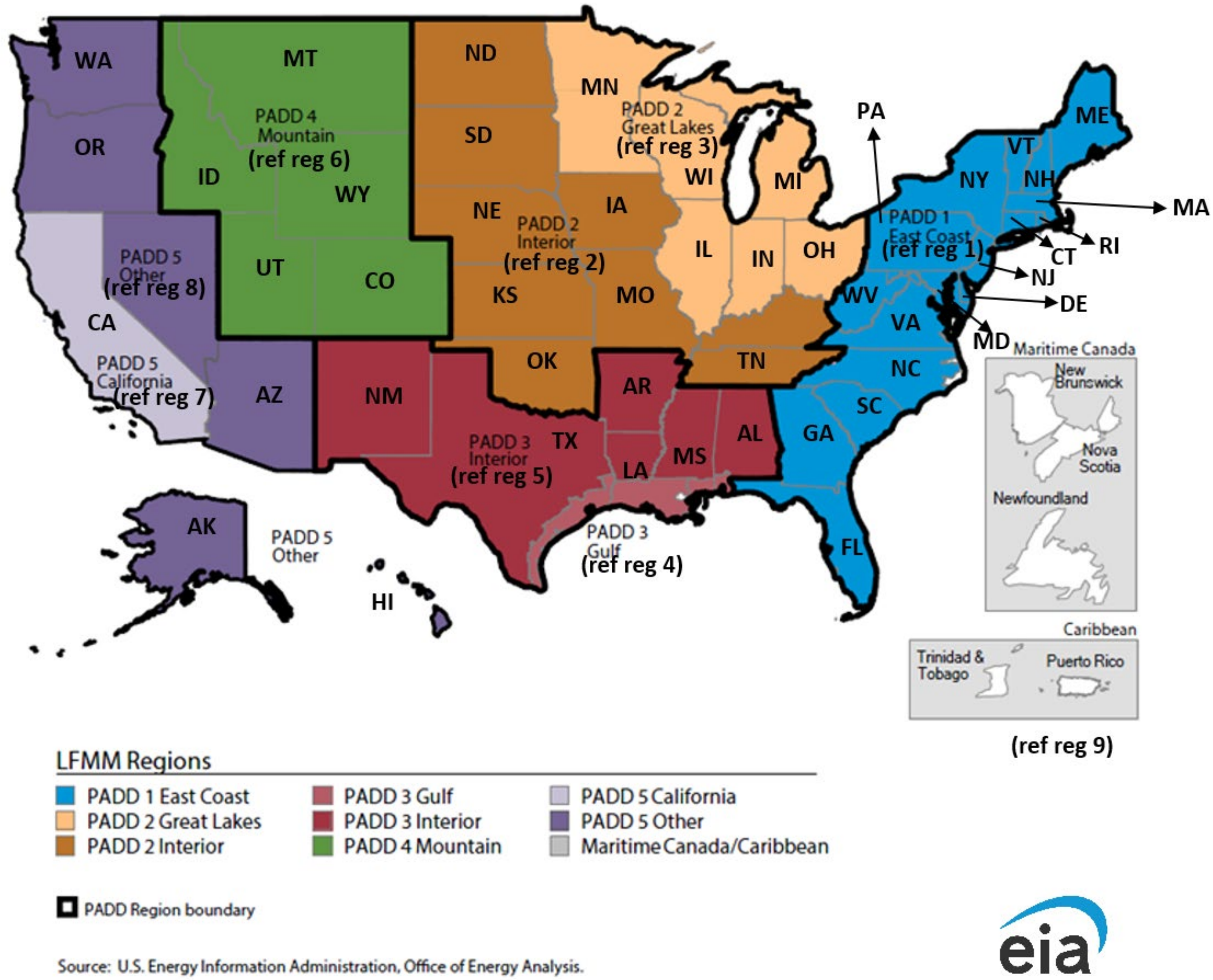
Model Rationale

Theoretical approach

The National Energy Modeling System (NEMS) is a general energy-economy equilibrium model that solves for quantities and prices of fuels delivered regionally to end-use sectors. The solution algorithm (Gauss-Seidel) is an iterative procedure used to achieve convergence between prices and quantities for each fuel in each region (U.S. census division). For example, the various demand modules use the petroleum product prices from the LFMM to estimate product demands. The LFMM then takes the petroleum product demands and, combined with information from other modules, estimates petroleum product prices. When successive solutions of energy quantities demanded and delivered prices are within a pre-specified percentage difference (convergence tolerance), the NEMS solution is declared converged. If the computed prices have not converged, new demand quantities are computed, passed to the LFMM, and the cycle is repeated. This process continues until a converged solution is found. See the description of the NEMS integrating module for a more complete understanding of the iterative process and convergence tests.

The LFMM uses a linear program (LP) to represent domestic liquid fuels production, consumption, distribution, and marketing operations. The model includes eight U.S. refinery production regions shown in Figure 2 based on PADDs (Petroleum Administration for Defense Districts) and sub-PADDs and one international region representing petroleum refining activity in eastern Canada and the Caribbean. A transportation network model represents transport of domestic crude oils to the refining regions and transport of petroleum products from the refining regions to the end-use census division (CD) demand regions. Changes in one refining region can affect operations in other refining regions because each demand region can be supplied by more than one refining region (if the transportation connections exist). Additional supply and demand for crude oil and petroleum products from and to the international market are represented by import and export curves that connect the international markets to the domestic transportation network described above.

Figure 2. Refining regions within the Liquid Fuels Market Module



Note: PADD=Petroleum Administration for Defense Districts, ref reg=refining region

An optimal solution is to minimize net total cost while simultaneously meeting regional demands and various constraints. The model estimates revenues from prices and product sales in the previous NEMS iteration and projects costs incurred from the purchase and processing of raw materials and from the transportation of finished products to the market. The liquid fuels production activities are constrained by material balance requirements on feedstocks and intermediate streams, product specification requirements, processing and transportation capacities, demand, and policy requirements. Economic forces also govern the decision to import or export crude oil or refined products into or out of U.S. regions.

Fundamental assumptions

The LFMM assumes that the liquid fuels production and marketing industry is competitive. The market will move toward lower-cost refiners (producers) who have access to crude oil (or non-petroleum feedstocks) and markets. The selection of feedstocks, process utilization, renewable fuel blends, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products. If domestic petroleum product 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 (or imports), thus restoring the supply and demand balance. Because the LFMM is an annual model, it cannot be used to analyze short-term petroleum market issues related to supplies, demands, or prices.

Model Code Structure

During each NEMS iterative solution (each iteration, each model year), product demand quantities, crude oil and petroleum product import and export curve data, and other data provided by the other NEMS demand and supply modules are used to update the LFMM linear program (LP) matrix. Once the updated LP provides an optimal solution, marginal crude oil and petroleum product prices and other material balance information are extracted, followed by some post-processing needed to convert results into output required by other models and reports. For example, additional costs (such as, state and federal taxes and distribution costs) are added to the marginal product prices to define domestic petroleum product prices for each end-use sector in each CD. In addition, refinery input and output volumes are reallocated from LFMM regions to CD reporting regions. System variables are updated, and reports are produced. The modification and optimization of the LFMM LP matrix are accomplished within a GAMS program using the Xpress solver. Appendix B describes the formulation of the LP representation in the LFMM.

The LFMM program code is a mix of GAMS and Fortran. The model starts operating when NEMS calls the Fortran subroutine REFINE—the main controlling subroutine for the LFMM. Through subroutine calls and a call to the main GAMS program lfshell.gms, the LFMM code initializes variables, reads data, updates and solves the LP, retrieves and processes results, performs *Short-Term Energy Outlook* (STEO) benchmarking, and generates report variables. Each major routine and its function are described below.

Main subroutines (refine.f, lfshell.gms)

The LFMM includes Fortran subroutines and GAMS programs. The Fortran subroutines are in the file refine.f: REFINE, RFHIST1, PMM_NEXTDATA, WRITE_INIT_GDX, WRITE_GDX, READ_GDX, and E85_Demand_Curve. The Fortran subroutine REFINE calls the GAMS program lfshell.gms, which subsequently calls other GAMS programs to read and prepare data, set up and solve the LP, and extract results for reporting to other NEMS modules.

Subroutine REFINE

REFINE is the main entry point into the LFMM from the rest of NEMS. It calls subroutines RFHIST1, Write_INIT_GDX, Write_GDX, E85_Demand_Curve, lfshell.gms, and Read_GDX.

Subroutines RFHIST1 and PMM_NEXTDATA

RFHIST1 reads the text file rfhist.txt, which contains historical and STEO-year data on crude oil imports, production capacity of petroleum refineries and non-petroleum liquid fuels plants, capacity utilization, product imports and exports, refinery product production, refinery gain, hydrocarbon gas liquids (HGL) imports and exports, etc. This routine also reads in the STEO benchmarking adjustment data used to transition between STEO results and near-term model projections of product prices. Additional detail on rfhist.txt is provided in Appendix G.

RFHIST1 calls PMM_NEXTDATA to iterate through the rfhist.txt file.

Subroutine WRITE_INIT_GDX

This subroutine writes relevant NEMS variables (available the first model year the LFMM is called) to a GAMS database (GDX) file: NEM_TO_LFMM_INIT.gdx. This GDX file is used for debugging purposes.

Subroutine WRITE_GDX

Writes relevant NEMS variables (every model year and iteration, beginning with the LFMM start year, 2010) to NEM_TO_LFMM1.gdx, a GAMS database (GDX) file. This GDX file contains all information provided by other NEMS models that the LFMM needs, including projection year, GDP data, product demands, domestic crude oil supply, import and export curves, etc. Data from this GDX file are later accessed by lf_nem.gms.

Subroutine READ_GDX

Reads LFMM LP results from LFMM_to_NEMS.gdx, a GAMS GDX file created by lfreport.gms that includes LFMM model results for other NEMS modules and NEMS reports.

Subroutine E85_Demand_Curve

Sets up an E85 demand curve using the logit function LFMM_FFVSHR to speed up convergence between the LFMM and the TDM. The data used to help define the curve are read from the input file rfinvest.txt. The final E85 demand curve data are written to E85.gdx, a GAMS GDX file that is later read by lfprep.gms.

lfshell.gms

lfshell.gms is the main entry point to the GAMS portion of the LFMM, and it is called by the Fortran subroutine REFINE. lfshell.gms performs the following:

- Calls lf_nem.gms to read the NEMS data from NEM_TO_LFMM1.gdx
- Calls lfprep.gms to read GDX input data files LFMinput.gdx, lfminset.gdx, and lfinvest.gdx and to prepare data used to define the LP matrix
- Calls lfmodel.gms to set up the LP model (decision variables, objective function, constraints)
- Sets capacity expansion parameters (fixed costs, learning, etc.) and limits
- Performs NPV (net present value) calculations to put all data on a consistent (nominal) year basis
- Creates California Low Carbon Fuel Standard (LCFS) carbon factors ready to be incorporated into the LP
- Uses expected demand for motor fuels to help calculate the renewable volume obligation (RVO) used to implement EPA Renewable Fuel Standard (RFS) requirements for each year
- Sets bounds on supply curves for crude oil, imported sugarcane ethanol, various feedstocks (corn, soyoil, biomass, etc.)
- Restricts capacity expansion for alternative fuel processes (celluloisic ethanol, gas-to-liquids, etc.) before a specified year
- Solves LP
- Calls lfreport.gms to write LP results to LFMM_TO_NEMS.gdx

LP Preprocessing (lf_nem.gms, lfprep.gms)

lf_nem.gms

Reads NEM_TO_LFMM1.gdx (created in refine.f), which contains all the data defined by other NEMS models that are needed to build the LP matrix (includes product demands, feedstock costs and supply curve data, energy conversion factors, etc.).

lfprep.gms

- Reads lfminset.gdx, which defines many of the sets used by the LFMM GAMS code
- Reads LFMinput.gdx, a GDX data file containing LFMM-specific input data (such as existing refinery and biofuels capacity and production characteristics, policy requirements, transport network costs and capacity, etc.) that reside in numerous Excel (xlsx) data files
- Reads lfinvest.gdx, a GDX data file created from process unit investment and learning data stored in lfinvestment.xlsx
- Creates mapping sets that mediate between NEMS regions and LFMM regions
- Initializes LP parameters based on NEMS variables read from NEM_TO_LFMM1.gdx
- Sets up supply curves for corn, soyoil, and other non-crude oil feedstocks using data provided by the RFM (via NEM_TO_LFMM1.gdx data file)
- Defines *waiver costs* for RFS and LCFS to ensure that the LP remains feasible

LP Formulation (lfmodel.gms)

lfmodel.gms specifies the LP decision variables, the constraints, and the objective function that represents the operations of liquid fuels production facilities in the United States, transport of liquids between supply and demand regions, and imports and exports of liquid fuels in the United States. The LP finds the minimum net cost of satisfying the set of liquid fuel demands given by the NEMS demand modules, subject to build, operation, and transport constraints (for example, processing capacity, volume balance, feedstock purchases, pipeline and transport capacities) and policy constraints (for example, RFS, LCFS, AB32, fuel specifications). The outputs of the LP include build, operation, and transport decisions, import and export decisions, and, most importantly, domestic crude oil and wholesale product prices. Appendix B contains a mathematical description of the LP model.

LP Post-Processing (lfreport.gms)

lfreport.gms writes the file LFMM_TO_NEMS.gdx, which contains the following important information passed from the LFMM to other NEMS modules and reports:

- Build and operation decisions for each liquid fuels production technology represented in the LFMM
- Regional domestic crude oil prices
- Wholesale product prices, based on shadow prices (duals) of selected LP constraints
- Retail product prices, based on regional wholesale prices and sector mark-ups representing taxes and distribution costs
- Energy purchases and process fuel use requirements
- Crude oil and petroleum product import and export decisions
- Items useful for debugging

Appendix A. Data and Outputs

This appendix has three parts:

1. Section A.1 describes how NEMS restart variables passed between the LFMM and the NEMS Integrating Module. Restart variables are listed in Appendix H.
2. Section A.2 describes data sources.
3. Section A.3 describes the data files used to create the LFMM's GDX data files that are loaded into the NEMS environment. The data files described in A.3 account for the largest portion of the LFMM data because they represent the liquid fuels process unit technologies and capacities, policy requirements, and product quality characteristics and specifications.

A.1 Variables and definitions

NEMS variables are passed to the LFMM via file NEM_TO_LFMM1.gdx. LFMM results (including product prices) are passed to the NEMS Integrating Module via variables included in the file LFMM_TO_NEMS.gdx. The most recent version of the NEMS text file varlistL.txt includes the NEMS variables and their associated Fortran-based *include* files that are passed between NEMS Fortran code and LFMM GAMS code which is provided in appendix. These variables are defined in another NEMS text file dict.txt, which we update annually. Restart variables are listed in Appendix H.

A.2 Data sources

Most of the initial data sources for the LFMM were developed by OnLocation, Inc./Energy Systems Consulting and their subcontractors. These data were based on both new analysis and existing analysis used in the LFMM's predecessor model, the Petroleum Market Module (PMM). For details on the original analysis, see the *LFMM Component Design Report*. Current data sources for the LFMM are described below.

Process technology and cost data

Refining process technology and cost data need to be periodically reviewed and updated because environmental legislation, lighter product slates, and ever-changing crude oil slates have spurred new process technology developments that affect existing processes, new processes, new crude oil types, and costs. Sources for new developments include research and other papers in industry journals, papers from industry conferences and surveys (such as the American Fuel and Petrochemical Manufacturers, AFPM), engineering and licensing contractor data, and published consultant studies.

Refinery capacity construction and utilization data

The base capacities for refinery process units are derived principally from EIA's annual *Refinery Capacity Report* (see section D.15). To represent planned capacity expansion, all announced projects were reviewed but only those that had reached the engineering, construction, or start-up stage were accepted. (Unit capacity is measured in volume per calendar day.) Historical process unit utilization is derived from EIA's *Petroleum Supply Annual*.

Crude oil supply and product demand data

The crude oil supply data are provided by two of the NEMS modules: HSM, which incorporates a production function to estimate domestic oil production (including for Alaska), and the International

Energy Module (IEM), which provides volumes and prices of international crude oil (in the form of supply curves by crude oil type) and non-U.S. crude oil demands (by crude oil type). The IEM also provides corresponding volumes and prices of international petroleum product supply and demand curves that the LFMM uses to determine product imports and exports to and from the United States. Individual crude oil streams for both domestic and imported crude oils are grouped into 11 crude oil categories, differentiated by API gravity, sulfur content, and yield characteristics. These categories are detailed in *Assumptions to the Annual Energy Outlook*.

Non-petroleum feedstocks

Data related to the following non-petroleum feedstocks are discussed in Appendix F:

- Natural gas plant liquids supply (Oil and Gas Supply Module)
- Coal supply curves (Coal Market Module)
- Natural gas prices (Natural Gas Market Module)
- Cellulosic biomass supply curves (Renewable Fuels Module)
- Corn supply and prices (Renewable Fuels Module and LFMM processing)
- Seed oils and bio-greases (Renewable Fuels Module and LFMM processing)

Products

Product demands are available from the NEMS restart file (determined by NEMS demand models and the electricity model) for a given scenario by year. The product list for the liquid fuels market includes:

- Motor gasoline
- CARB motor gasoline
- E85
- Diesel
- CARB diesel
- Jet fuel
- Heating oil
- Distillate oil
- Residual oil (resid)
- HGL
- Naphtha (petrochemical feedstock)
- Petroleum coke
- Ethane
- Propane
- Iso-butane and n-butane
- Natural gasoline
- Propylene
- Others (lubes, aviation gasoline, asphalt, benzene, toluene, xylene)

Some coproducts are also represented.

Product specification/grade split data

For the United States, surveys by industry organizations such as AFPM, API, and NPC, together with government sources such as U.S. Department of Defense, provide relatively frequent and detailed insights into actual U.S. product qualities and grade splits. These data are important for establishing case studies.

Product yield and quality blending data

In addition to the general sources already mentioned, a number of sources relating to specific properties are:

- Cetane number: API Refining Dept., Vol. 61, p.39 and appendix for the modified ASTM D976 80 Equation (George Unzelman).
- Net heat of combustion: ASTM D3338 (API range 37.5-64.5) (relaxing ASTM D2382).
- Weighted percentage hydrogen: ASTM Method D3343 (replacing D1018)
- Smoke point versus hydrogen content: empirical correlation developed by EnSys Smoke point to Luminometer number conversion, ASTM D1322.
- Viscosity prediction: based on the work of PLI Associates (Dr. Paul S. Kydd) and from the Abbott, Kaufman, and Domashe correlation of viscosities. (See PLI report "Fuel and Engine Effect Correlations, Task 1.1, Computerize Fuel Property Correlations and Validate"). Viscosity interpolation included and based on computerized formulae for ASTM charts.
- Viscosity blending indices: computerization of Gary & Handwerk formulae, p.172 (left-hand side).
- Static and dynamic surface tensions: API Technical DataBook method.
- Flash point blending index numbers: Gary & Handwerk, p.173.
- Pour point blending indices: Gary & Handwerk, p.175.
- Reid vapor pressure (RVP) blending indices have been gathered from several public and in-house sources and have been verified against Gary & Handwerk, p.166.

Research octane number (RON) and motor octane number (MON) blending deltas reflective of base gasoline sensitivity have been drawn from many sources and averaged.

Transportation data

LFMM transportation rates (dollars per volume or mass transported) and capacity data for the United States are represented for transport of crude oil and petroleum products by pipeline, rail, truck, vessel, and barge. Over the years, crude oil and petroleum product pipeline capacity and tariff data have been updated based on research through filings by the Federal Energy Regulatory Commission (FERC), as well as online searches and news releases related to pipeline companies.

Units of measurement

The general rule adopted for input data in the LFMM is that quantities of crude oil and refinery products are in thousands of barrels per calendar day, prices or costs are in 1987 dollars per barrel, and quantities of money are in thousands of 1987 dollars per calendar day.

Exceptions to the above rule:

- The LP itself uses nominal-year dollars for each iteration of each NEMS year.
- Gases lighter than propane are measured in thousands of barrels of fuel oil equivalent (FOE) per calendar day. These measurements are based on the volume conversion factors in Table A-1.

Table A-1. Volume conversion factors for gases lighter than propane

Gas stream	Code	Barrels of fuel oil equivalent per pound	Cubic feet per barrels of fuel oil equivalent
Hydrogen	H2,H2U	.009620	19,646
Hydrogen sulfide	H2S	.001040	10,145
Methane/natural gas	NGS,CC1	.003414	6,917
Ethane	CC2	.003245	3,861
Process gas	PGS	.003245	3,861

- One barrel FOE (fuel oil equivalent) is 6.287 million British thermal units (MMBtu).

The assumed Btu content for other major refinery streams is shown in Table A-2.

Table A-2. British thermal units per barrel for other streams

Stream	Code	Million British thermal units per barrel
Gasoline	(multiple)	5.057
Jet fuel	JTA	5.67
Diesel (ultra-low sulfur diesel)	DSU	5.77
No. 2 heating oil	N2H	5.825
Residual oil	N6I,N6B	6.287
Liquefied petroleum gas	LPG, CC3	3.532
Ethanol	ETH	3.558

- Yields of coke are measured in short tons per barrel, and demands are in short tons per day. A factor of 5.0 crude oil equivalent (COE) barrels per short ton is used. Heat content is 6.024 MMBtu/b.
- Yields of sulfur are also measured in short tons per barrel, and demands are in short tons per day. A factor of 3.18 barrels per short ton is used.
- Process unit capacities are generally measured in terms of feedstock volume. Exceptions are process units, principally those with gaseous feeds and liquid products, whose capacities are measured in terms of product volume.
- Process unit activity levels for SUL represent the production of short tons of sulfur per day.

- Quality and specification units are those specified in each ASTM test method or are dimensionless (as in the case of blending indices). Sulfur specs are defined in parts per million for both gasoline and diesel blend streams but are converted to volume percentage (using specific gravity) for use in the LP.
- Steam consumption is in pounds per barrel (lb/b). Thus, an activity in Mb/cd consumes steam in thousands of pounds per day (Mlb/day). Steam generation capacity is in millions of pounds per day (MMlb/day). The consumption of 0.00668 fuel oil equivalent barrels per day to raise 1 pound per hour of steam is equivalent to 1225 Btu per pound steam (assuming 70% energy conversion efficiency).
- Electricity consumption is in kWh/b. Generation is in MWh/cd (megawatthours per calendar day).

A.3 Data tables

LFMinset.gdx contains names and content of sets used by the LFMM but not by other NEMS modules. Table A-3 presents the GAMS files and corresponding set names that are generated for the LFMinset.gdx file. Some example sets include:

- Process, ProcessMode: set of all production processes and their operating modes
- Stream: set of all physical and non-physical streams
- RecipeProd: set of products produced according to a specific recipe
- SpecProd: set of products formed from streams blended to meet various product-specific quality specifications rather than according to a recipe (diesel, jet, No. 2 heating oil, California BOB, conventional BOB, reformulated BOB, residual fuel oil)
- DistProp, GasProp, ResidProp: set of quality specifications that need to be met for selected distillates, motor gasolines, and residual fuel
- EndProduct, EndProductNGL (alias NGLProduct): set of products that are demanded by the various NEMS demand modules. About equal to the union of sets SpecProd and RecipeProd.
- CoProduct: set of coproducts manufactured incidentally to the production of end products

Table A-3. GAMS files used to make LFMinset.GDX

GAMS file (.gms)	Set names
SetBldStep	BldStep
SetIntStream	Crude, CrudeAll, CoalStr, BioStr, FCOType, NGLInputStr, MethanolInputStr, Purchase_Streams, AltPurchase_Streams, OtherPurchase_Streams, RefInputStr, Fueluse_Streams, EthStreamsRFS, EthStreamNoRFS, EthStream, Utility, LightGases, LightGasesExNaphtha, NaphthaLightBiofuels, NaphthaLightNPF, NaphthaLightPet, NaphthaMedium, NaphthaHeavyBiofuels, NaphthaHeavyNPF, NaphthaHeavyPet, ReformateBiofuels, ReformateNPF, ReformatePet, Alkylate, GasolineCat, GasolinePoly, IsomerateBiofuels, IsomerateNPF, IsomeratePet, PetNaphtha, KeroseneBiofuels, KeroseneNPF, KerosenePet, LightCycleOil, DieselBiofuels, DieselNPF, DieselPet, DieselHeavy, GasOilLight, GasOil, GasOilHeavy, PetDistillate, ResidualOil, Raffinate, PetResid, Solids, NaphthaAndLighter, Int_Misc, IntStream_Other, IntStream
SetInvParam	InvParam
SetLCFS	LCFS_BioImport_PetStream, LCFS_BioImports, LCFS_BioMode, LCFS_BioProcess
SetLrn	LearningProcess, LrnParam, LrnSpeed, LrnPhase, MoreLrnParam
SetMarkup	MarkupFuel, MarkupSector
SetMisc	Period, PrcPeriod, BldPeriod, t, tIdx, CapExpYr, ReportYr, Step
SetNFBaseYr	NFBaseYr
SetProcess	PetroleumProcess, CornProcess, NonCornProcess, EthanolProcess, AltFuel_Process, NPFProcess
SetProcessMode	ProcessMode
SetProcessRisk	BldRiskClass, ProcessRisk
SetProduct	EndProductGas (alias GasProduct), EndProductDist, EndProductResid, EndProductMisc, EndProduct, CoProduct, EthCoproduct, CoProductSales, endProductNGL (alias NGLProduct), RecipeProd, RecipeOut
SetProperty	Property
SetRcpMode	RcpMode
SetRefType	RefType
SetRegionality	Source, DomRefReg, NonDomRefReg, RefReg, ActiveDem, CenDiv, CoalDReg, CoalSReg, CoalDReg_2_Census, NGPL_2_RefRe, State
SetRFSCategory	RFSCategory (alias RFSCategoryA)
SetSector	DieselSector, LPGSector
SetSpecProd	DistSpecprod, GasSpecProd, ResidSpecProd, SpecProd
SetSpecProdProp	GasProp, DistProp, ResidProp
SetStream	StreamOVC, Stream, NoMat, NonCrudeUtil, RecipeInputs, RecipeEnd
SetTranMode	MrineMode, NonMarineMode, TranMode

LFMinput.gdx defines parameters used by the LFMM and created from input data originally stored in a group of Microsoft Excel data files. These Excel files are composed of multiple worksheets (highlighted in

Table A-4). The following are examples of a few parameters in the LFMinput.gdx file that originated in an Excel file.

- ProcessTableCrude: input streams, output yields, and fuel and utility requirements for each Process and ProcessMode represented in the LFMM
- RecipeBlending: a variety of recipe definitions available to produce the products listed in the set RecipeProd
- StreamProp: stream properties (API, sulfur (SPM), octane (CON), etc.) used to meet quality specifications (listed in DistProp, GasProp, and ResidProp) defined by DistSpecMax/Min, GasSpecMax/Min, and ResidSpecMax/Min for blending of products listed in the set SpecProd

Table A-4. Excel files used to make LFMINPUT.GDX

Excel file (.xlsx)	Worksheets
lfblending	Properties, RCP, StreamSpecProd, DieselFrac
lfcapacity	ForImport
lfccats	CCATSDAT_CST_ETH_INV, CCATSDAT_CST_ETH_OM, CCATSDAT_SUP_ETH_45Q, CCATSDAT_SUP_ETH_NTC
lfcontrol	CoalDReg-to-RefReg, Census-to-RefReg, StateMaps, Streams, Processes, StreamFactors
lfdistconstr	RefReg-to-RefReg Cap Import, RefReg-to-RefReg Cost Import, RefReg-to-Census Cap Import, RefReg-to-Census Cost Import, IntReg-to-RefReg Cap Import, IntReg-to-RefReg Cost Import, RefReg-to-IntReg Cap Import, RefReg-to-IntReg Cost Import, E15MaxPen
lfdistcosts	StateFuelTax, ProductMarkups, FedFuelTax, EnvMarkups
lffeedstock	SPR_Withdraw, Crude_Import_Cap, Crude_Import_Cost, Crude_Export_Cap, Crude_Export_Cost, Allowed_Crude_Use, Crude_Import_Region, Crude_Export_Region, CornPriceExp, CornTranCost, SeedOilQnty, GrainQnty
lfimportpurch	ForImport, BrzAdvEthProd, BrzEthDmd (obsolete as of AEO2020), NonUSEthDmd, FBDImpQuant, FBDImpCoef
lfnonpetroleum	ForImport, EDH, EDM, IBA, SEW, NCE, AET, CLE, BPU, FBD, GDT, SAF
lfpetcrackers	FCC, RGN, HCD
lfpetcrudeunits	ACU, LTE, VCU, CSU
lfpetenviro	SUL, ARP, DDA
lfpetother	LUB, SGP, UGP
lfpetseparation	LNS, FGS, DC5, DC4
lfpetupgraders	DDS, SDA, KRD, ALK, BSA, RCR, RSR, NDS, C4I, CPL, FDS, GDS, PHI, TRI
lfpolicy	RFSMandates, RFSScores, RFSCategory, RFSWaiver, LCFS_AltVehicles, LCFS_Penalty_Cost, LCFS_Target, LCFS_BioStreams, LCFS_PetStreams, LCFS_BioImports, CFP_AltVehicles, CFP_Penalty_Cost, CFP_Target, CFP_BioStreams, CFP_PetStreams, CFP_BioImports, WACFS_AltVehicles,

Excel file (.xlsx)	Worksheets
	WACFS_Penalty_Cost, WACFS_Target, WACFS_BioStreams, WACFS_PetStreams, WACFS_BioImports, AB32_CapAdjFactor, AB32_AssistFactor, AB32_BenchFactor, AB32_Control, ULSD_N2H, State_Biodiesel, BiofuelSubsidy
lfproducts	LPGPricing, CoproductPricing, Gas_Spec_UB, Gas_Spec_LB, Dist_Spec_LB, Dist_Spec_UB, Resid_Spec_UB, Resid_Spec_LB
lfrefpurch	1_RefReg, 2_RefReg, 3_RefReg, 4_RefReg, 5_RefReg, 6_RefReg, 7_RefReg, 8_RefReg, 9_RefReg
lftransfers	TRS
lfutilities	FUM, KWG, STG, CGN, H2R

A third file, LFinvest.gdx, contains investment information that we obtained from original data that reside in another set of worksheets in another Microsoft Excel file (lfinvestment.xlsx) listed in Table A-5. The following describes some of the data in the gdx file that originated in the Excel worksheets.

- CapExpSize, CapExpISBL, CapExpLabor: these represent the unit size, ISBL cost, and expected labor associated with building a specific process unit
- InvFactors, InvLoc: list of multipliers associated with added investment costs as a function of base capital cost
- FedTax, StateTax: tax rates used during investment calculations
- LearningData: data specifically used to adjust the calculated capital investment to represent cost improvement as a result of learning

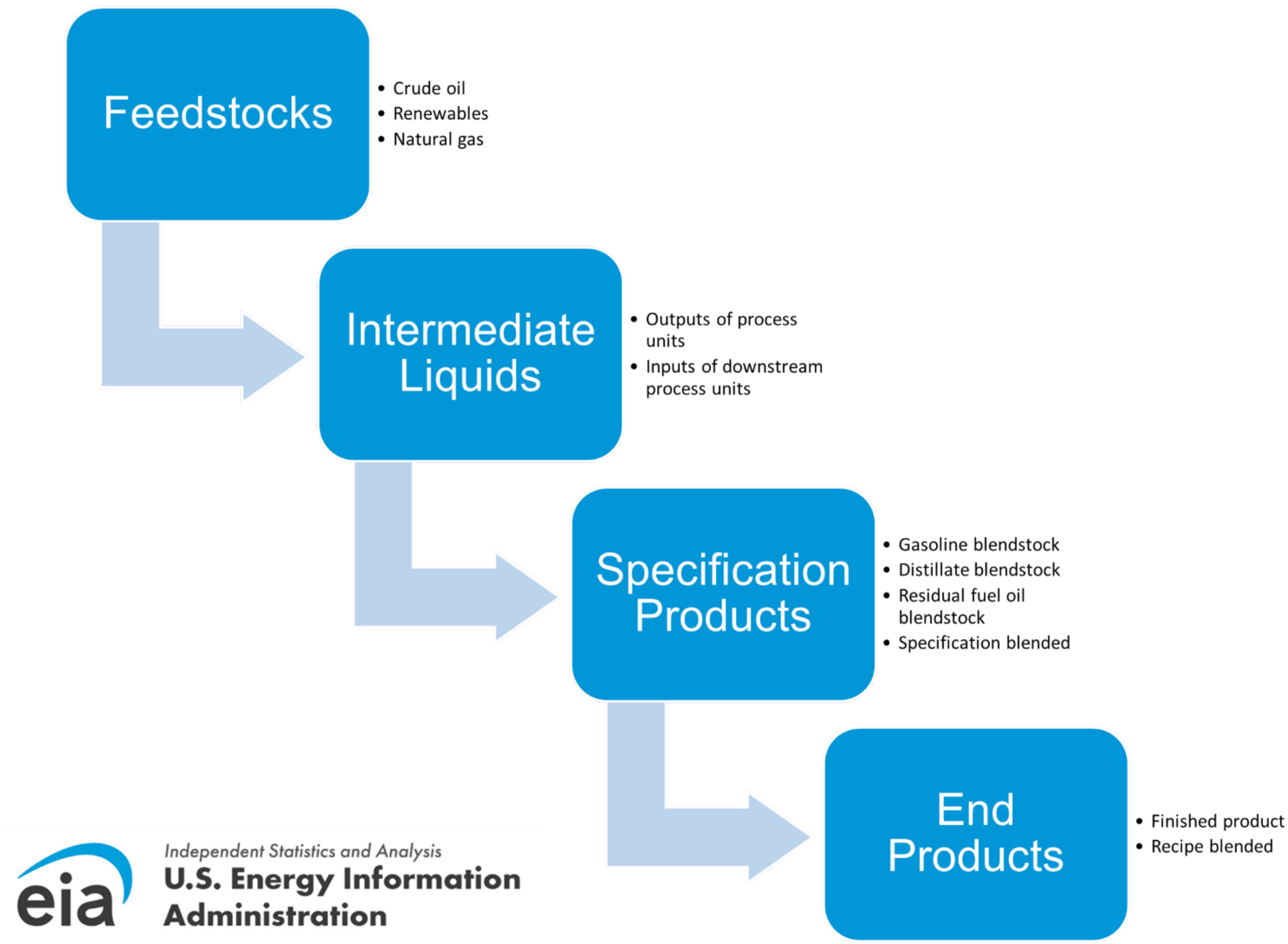
Table A-5. Excel files used to make LFinvest.GDX

Excel file (.xlsx)	Worksheets
lfinvestment	CapCostImp, NFImport, StateTax, FedTax, RegionalData, InvestmentFactors, Capital Costs, N-F Indices, Learning, Learning2, AFGrowthRates, AFBldSteps (and OptimismWorksheet)

Appendix B. Mathematical Description of Model

The LFMM models the transformation of feedstock into intermediate streams that are blended to create intermediate and finished products (Figure 3). The LFMM models two types of blending: specification-blending and recipe-blending for intermediate and finished products. In specification-blending, intermediate streams are blended such that the resulting specification-product stream (Table B-1) meets certain quality restrictions (or specifications). For example, various petroleum streams are mixed in different proportions to make a gasoline blendstock that meets sulfur limits, RVP requirements, benzene restrictions, and other required specifications. In recipe-blending, intermediate streams (including specification-product streams) are blended in fixed proportions to make final products, such as E10 gasoline blended from 90% gasoline blendstock and 10% denatured ethanol.

Figure 3. Flow chart of stream flows



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

Table B-1. Specification-blended intermediate products

Specification-product	Description
Gasoline blendstock	
CaRBOB	California reformulated blendstock
CBOB	Conventional blendstock
RBOB	Reformulated blendstock
Distillate	
CarbDSU	California ultra-low sulfur diesel
DSL	Low-sulfur diesel
DSU	Ultra-low sulfur diesel
JTA	Jet fuel
N2H	No. 2 heating oil
Residual fuel oil	
N6B	No. 6 fuel oil, high sulfur
N6I	No. 6 fuel oil, intermediate sulfur

The LFMM models 79 recipes for blending recipe-products. Some recipes have single input streams, such as the recipes for the various hydrocarbon gas liquids. Other recipes comprise multiple input streams, such as RCP_RFG10a, which blends 90% RBOB gasoline blendstock and 10% denatured corn ethanol to make recipe-product RFGout (Table B-2).

The LFMM is formulated as a linear program (LP) that is implemented in GAMS. The GAMS code has been structured based on functionality:

- lfshell.gms is the main GAMS program in LFMM that organizes the code structure (calls other GAMS code that prepares the LP to be solved and extracts results), sets bounds in the LP, converts preprocessed data to the net present value (NPV) format required by the LP, and instructs the LP to solve.
- lf_nem.gms defines the data sets and parameters and reads the relevant NEMS data provided by other NEMS modules.
- lfprep.gms also defines data sets and parameters, reads in LFMM-specific data, and prepares the data needed to set up the LP.
- lfmodel.gms defines the objective function, decision variables, and constraints in the LP.
- lfreport.gms extracts solution results from the LP and writes results to be sent to other NEMS modules.

Table B-2. Recipe-blended (finished) products

Recipe-product	Description
Distillate	
CarbDSUout	Diesel, ultra-low sulfur, California, and renewable diesel
DSLout	Diesel, low-sulfur, and renewable diesel
DSUout	Diesel, ultra-low sulfur, and renewable diesel
JTAout	Jet fuel
N2Hout	No. 2 heating oil
Gasoline-like	
CaRBOBout	E10 from CaRBOB blendstock and ethanol
CFG15out	E15 from CBOB blendstock and ethanol
CFGb16out	Bu16 from CBOB blendstock and biobutanol
CFGout	E10 from CBOB blendstock and ethanol
E85out	E85 from CBOB blendstock and ethanol
RFG15out	E15 from RBOB blendstock and ethanol
RFGb16out	Bu16 from RBOB blendstock and biobutanol
RFGout	E10 from RBOB blendstock and ethanol
Residual fuel oil	
N6Bout	No. 6 fuel oil, high-sulfur
N6Iout	No. 6 fuel oil, low-sulfur
Hydrocarbon gas liquids	
CC2out	Ethane
LPGout	LPG (propane)
UC3out	Propylene
NC4out	Normal butane
IC4out	Isobutane
NATout	Natural gasoline / pentanes+
Other	
ASPHout	Asphalt / road oil
AVGout	Aviation gasoline
BTXout	Benzene-toluene-xylene
COKout	Petroleum coke
LUBout	Lubricants
PCFout	Petrochemical feedstock

Three distinct time periods are represented in the LFMM LP: Period 1 (current NEMS year), Period 2 (next NEMS year), Period 3 (next 19 NEMS years after Period 2). Period 1 represents operations based on existing capacity, without the option to build additional capacity. Period 2 and Period 3 represent operations based on existing capacity along with the capability to add new capacity. The Period 1 LP is executed every NEMS iteration (in other words, multiple times each NEMS year); the LP representing Period 2 and Period 3 is executed in the last iteration (after NEMS sets FCRL=1) of each NEMS year.

Period 2 capacity expansion decisions from the last iteration of a particular NEMS year are added to the Period 1 existing capacity for the following NEMS year. Period 3 capacity expansion decisions are discarded; however, Period 3 representation helps to inform the capacity expansion decision made in Period 2 by representing the economic impact over the life of the new expansion.

The following information serves as a glossary of terms and abbreviations used in this section to define the LFMM LP model.

Notation

Table B-3. Sets

Set name	Description
Biostr	= biomass feedstock types
Crude	= crude oil types (based on API gravity and sulfur content)
EthStream	= ethanol types (from corn, sugar cane, cellulosic, etc.)
EndProductGas	= gasoline products, a subset of RecipeProd
IntStream	= all intermediate streams (including streams blended into product) and feedstock streams (including crude oil and biofuel feedstocks), no product streams
IntStream_Other	= all intermediate streams, but not feedstock or products streams
RecipeProd	= recipe-blended products
RFSCategory	= Renewable Fuel Standard categories: total, advanced, biomass-based diesel, cellulosic
SpecProd	= specification-blended products

Table B-4. Indexes

Index	Description
b	= biomass feedstock type
c	= crude oil type
cp	= coproduct type
$\hat{e}$	= emission type (sulfur dioxide, mercury)
j	= general index for streams, which can take values for biodiesel *b*, crude oil *c*, ethanol *e*, product *p*, or stream type $\hat{s}$
m	= transportation mode
p	= product
$\hat{p}$	= process mode
q	= specification property type
r, r'	= region
$\hat{r}$	= recipe
s	= step on supply curve or demand curve
$\hat{s}$	= stream type, including *b*, *c*, *j*, *p*, *u*
u	= utility type

Table B-5. Parameters used in the objective function

Parameter	Description
Cbim_{rs}	= cost of FAME (fatty acid methyl ester) biodiesel (FBD) imports into region *r* purchased on step *s* of the supply curve (FBDImpPrice)
Crim_{rs}	= cost of renewable diesel (RDH) imports into region *r* purchased on step *s* of the supply curve (RDHImpPrice)
Cbr_{s}	= cost of sugarcane (advanced) ethanol on import supply step *s* (EthImpSupPrc)
Cbrex_{r}	= transport cost per unit export of material in stream $j \in \mathrm{E}$ from region *r* to the world (mostly Brazil) (TranCostToBrazil)
Cbrim_{r}	= transport cost per unit import of material in stream $j \in \mathrm{E}$ to region *r* from the world (mostly Brazil) (TranCostFromBrazil)
$\mathrm{Cbld}_{\hat{p}r}$	= net present value of capital costs and fixed operating cost of newly-added capacity of process mode $\hat{p}$ in region *r* (BuildCost)
$\mathrm{Ccr1}_{s}$	= base cost of crude oil at step *s* of the supply curve, dollars per barrel (CrudePriceTotal)
$\mathrm{Ccr2}_{cs}$	= incremental cost of crude oil type *c* at step *s* of the supply curve, dollars per barrel (CrudePriceIncremental)
Ccrex_{crs}	= cost to export crude oil type *c* from region *r* at step *s,* dollars per barrel (CrudeExportCost)
Ccrim_{crs}	= cost to import crude oil type *c* from region *r* at step *s,* dollars per barrel (CrudeImportCost)
Ccrint_{cs}	= cost of non-U.S. demand for crude oil type *c* at step *s,* dollars per barrel (NonUSCrudeDemandPrice)
$\mathrm{Cfxoc}_{\hat{p}r}$	= fixed operating cost of existing capacity of process mode $\hat{p}$ in region *r* (FXOCCost)
$\mathrm{Cm}_{\hat{s}r's}$	= cost of stream $\hat{s}$ purchased in region r' at step *s* of the supply curve (BiomassPrc, CoalPrc)
Cpex_{pr}	= cost of exports of product *p* from region *r,* dollars per barrel (ImportPrice, NGLImportCost, GlobalImpPrice)
Cpim_{pr}	= cost of imports of product *p* to region *r,* dollars per barrel (ExportPrice, NGLExportCost)
Cpim_{ps}	= cost to purchase imported product *p* at step *s,* dollars per barrel (ImportPrice)
$\mathrm{Cproc}_{\hat{p}r}$	= cost per unit of activity on process mode $\hat{p}$ in region *r*, typically in dollars per barrel of output (OpVarCost)
$\mathrm{Cpur}_{\hat{s}rs}$	= cost to purchase stream $\hat{s}$ in region *r* on step *s* of the supply curve (RefInpPrc)
$\mathrm{Crcp}_{\hat{r}}$	= cost per unit of activity on recipe $\hat{r}$ (RecipeOVC), typically in dollars per barrel of output.
$\mathrm{Ctran}_{jrr'}$	= cost to transport material in stream *j* from region *r* to region r' (REFtoREFTranCost, INTtoREFTranCost, REFtoINTTranCost, REFtoCDTranCost)
Cu_{ur}	= cost per unit of utility *u* used in region *r* (UtilityPrice). Units of measure vary.
Rpex_{ps}	= revenue per unit of product *p* on each step *s* of the product export demand curve, dollars per barrel (ExportPrice)
Rce_{s}	= revenue per unit of corn ethanol on each step *s* of the ethanol export demand curve, typically in dollars per barrel (EthExpDmdPrc)
Rcp_{pr}	= revenue per unit of coproduct *cp* in region *r*, typically in dollars per barrel (CoproductPrice)

Note: Unless otherwise indicated, objective function parameters are in nominal dollars per barrel (nom$/b).

Table B-6. Parameters used in constraints

Parameter	Description
$A_{\hat{p}j}$	= units of *j* produced or consumed per unit of activity of process mode $\hat{p}$ (ProcessTable)
$A_{\hat{p}u}$	= utility *u* used per unit of activity of process mode $\hat{p}$. Units of measure vary.
D_{pr}	= demand for product *p* in region *r*
$G_{\hat{s}r}$	= electricity market demand for stream $\hat{s}$ in region r. Units of measure = billion British thermal units per day
$H_{\hat{e}r\hat{s}}$	= emissions of stream type $\hat{e}$ per unit of coal stream $\hat{s}$ purchased in region *r*. Units of measure vary (for example, 1,000 tons of sulfur dioxide per MMBtu of coal; 0.001 tons mercury per MMBtu of coal).
$LCFSfactor_{p\hat{r}}$	= amount by which product *p* produced by recipe $\hat{r}$ exceeds the California Low Carbon Fuel Standard (LCFS) target carbon intensity
$LCFSfactor_{p,lg}$	= amount by which landfill gas exceeds the California Low Carbon Fuel Standard (LCFS) target carbon intensity
$MaxE15frac$	= maximum fraction of total motor gasoline demand that can be E15
N	= non-U.S. demand for ethanol
P_{cr}	= domestic production of crude oil type *c* in region *r*
$\hat{P}_{q\hat{s}}$	= level of property *q* in stream $\hat{s}$ (StreamProp)
$\hat{P}_{qp}^{max}$	= maximum level of property *q* in product *p.* Units of measure vary.
$\hat{P}_{qp}^{min}$	= minimum level of property *q* in product *p.* Units of measure vary.
$R_{\hat{s}\hat{r}}$	= volume of stream $\hat{s}$ in recipe $\hat{r}$
$RFSScore_{k\hat{s}}$	= credits (ethanol-equivalent volume) of stream $\hat{s}$ toward Renewable Fuel Standard (RFS) category *k*
$RFSTarget_k$	= target volume for RFS category *k*, in ethanol-equivalent volume
$T_{rr'}$	= maximum volume of ethanol that can be transported from region *r* to region *r'*
$T_{mrr'}$	= maximum (non-ethanol) volume that can be transported via mode *m* from region *r* to region *r'*
UE_{rs}	= upper limit on total exports of crude oil from region *r*
UI_{rs}	= upper limit on total imports of crude oil into region *r*
$UE_{rr'}$	= upper limit on product shipments (exports) from region *r* to international region r'
$UI_{r'r}$	= upper limits on product shipments (imports) from international region $r'$to region *r*

Note: Unless otherwise indicated, constraint parameters are in thousands of barrels per day (Mb/d). The corresponding GAMS parameter name is listed in parentheses following each parameter definition.

Table B-7. Decision variables

Variable	Description
a_{ur}	= amount of utility *u* used in region *r* (UTILPURCH)
$b_{\hat{s}r}$	= amount of stream $\hat{s}$ that is purchased and then used in region *r* (REFPURused)
cp_{pr}	= total coproduct *p* produced in region *r* (COPRODUCTS)
$d_{\hat{s}rs}$	= amount of stream $\hat{s}$ in region *r* that is purchased on step *s* of the supply curve (REFPURCH)
e_{pr}	= exports of product *p* from region *r* (EXPORTS)
e_{crs}	= exports of crude oil type *c* from region *r* at step *s* (CRUDEEXPORT)
e_{ps}	= total exports of product *p* to the world on step *s* of the demand curve (PRODEXP)
$E_{\hat{p}r}$	= usage of existing capacity of process mode $\hat{p}$ in region *r*. Upper-bounded by the existing capacity. (OPERATECAP)
$\hat{E}_{\hat{p}r}$	= newly added capacity of process mode $\hat{p}$ in region *r*. Set to zero for Period 1. (BUILDS)
$f_{\hat{e}r}$	= emissions of type $\hat{e}$ in region *r*
g_r	= volume of sugar cane (advanced) ethanol imported from the world into region *r* (ETHIMP)
$\hat{g}_r$	= volume of corn ethanol exported to the world from region *r* (ETHEXP)
h_{pr}	= recipe product *p* available in region *r* (TOTPROD)
lg_{pr}	= landfill gas available to recipe product *p* carbon intensity target in region *r* (LCFS_LandfillGas)
i_{rs}	= imports of biodiesel into region *r* purchased on step *s* of the supply curve (BIODIMP)
i_{pr}	= total imports of product *p* into region *r* (IMPORTS, BIODIMPref, RENEWDIMPref)
i_{crs}	= imports of crude oil type *c* into region *r* at step *s* (CRUDETRANS)
$\hat{\imath}_{ps}$	= total imports of product *p* from the world at step *s* (PRODIMP)
j_{rs}	= imports of renewable diesel into region r purchased on step s of the supply curve (RENEWDIMP)
ke_s	= total world demand for corn ethanol exported from the United States at step *s* (ETHEXPUSdmd)
ki_s	= total sugar cane (advanced) ethanol available for import to the United States at step *s* (ETHIMPUSsup)
$\widehat{m}_{\hat{s}r'r}$	= amount of stream type $\hat{s}$ purchased in region r' used for liquid fuels production in region *r* (BIOXFER, COALXFER)
$m_{\hat{s}r's}$	= amount of stream $\hat{s}$ purchased in region r' at step *s* of the supply curve (BIOPURCH, COALPURCH)
n_{cs}	= total non-U.S. demand for crude oil type *c* at step *s* (CRUDENONUS)
$t_{jrr'}$	= shipments of material in stream *j* from region *r* to region r' (RefRefTRAN, PRODImpTRAN, PRODExpTRAN)
w'_s	= total world consumption of all crude oil types at step *s* of the total supply curve (CRUDETOTAL)
w_{cs}	= total world purchases of crude oil type *c* at step *s* of the supply curve (CRUDEPURCH)
$x_{\hat{p}r}$	= activity on process mode $\hat{p}$ in region *r* (PROCMODE)
$\hat{x}_{r\hat{r}}$	= activity on recipe $\hat{r}$ in region *r* (RECIPEMODE)
$\check{x}_{rp}$	= volume of recipe-product *p* blended in region *r* (RECIPETOPROD)
$y_{jr\hat{r}}$	= volume of stream *j* recipe-blended into recipe-products in region *r* via recipe $\hat{r}$ (ToRECIPEBLEND)
$z_{\hat{s}pr}$	= volume of stream $\hat{s}$ specification-blended into specification-product *p* in region *r* (ToSPECBLEND)

Note: Unless otherwise indicated, decision variables are in thousands of barrels per day (Mb/d). Corresponding GAMS names are in parentheses after each variable description. Variables indexed by step *s* have upper bounds.

Objective function

The objective function represents net annual cost in thousands of nominal dollars per calendar day. In the formulation below, multiple summation indexes are suppressed. In actuality, each term is summed over all the indexes of the summand. The LP has three periods over which costs are considered: Period 1 represents the current NEMS year (for operating decisions), Period 2 represents the next NEMS year (for capacity expansion decisions), and Period 3 represents the subsequent 19 years as a look-ahead period that enables capital expansion to meet upcoming demands while avoiding stranding capital assets. The objective function minimizes net annual costs, as defined below.

Minimize total cost minus applicable revenue from exports and coproduct sales =

Fixed operating cost of processing units

$$\sum \mathrm{Cfxoc}_{\hat{p}r} E_{\hat{p}r} \tag{1}$$

Build cost of processing units

$$+\sum \mathrm{Cbld}_{\hat{p}r} \hat{E}_{\hat{p}r} \tag{2}$$

Variable operating cost of processing units

$$+\sum \mathrm{Cproc}_{\hat{p}r} x_{\hat{p}r} \tag{3}$$

Crude oil purchase cost

$$+\sum \mathrm{Ccr1}_{s} w'_{s} + \sum \mathrm{Ccr2}_{cs} w_{cs} \tag{4}$$

Transport cost to export crude oil and import crude oil

$$+\sum \mathrm{Ccrex}_{crs} e_{crs} + \sum \mathrm{Ccrim}_{crs} i_{crs} \tag{5}$$

Cost of crude oil to non-U.S. users

$$+\sum \mathrm{Ccrint}_{cs} n_{cs} \tag{6}$$

Cost to purchase imported sugar cane (advanced) ethanol from the world

$$+\sum \mathrm{Cbr}_s ki_s \tag{7}$$

Cost to transport sugar cane (advanced) ethanol imported from the world

$$+\sum \mathrm{Cbrim}_r g_r \tag{8}$$

Cost to transport corn ethanol exported to the world

$$+\sum \mathrm{Cbrex}_r \hat{g}_r \tag{9}$$

Utility costs

$$+\sum \mathrm{Cu}_{ur} a_{ur} \tag{10}$$

Cost of non-crude oil refinery input streams and interregional crude oil and petroleum product transport

$$+\sum \mathrm{Cpur}_{\hat{s}rs} d_{\hat{s}rs} \tag{11}$$

$$+\sum \mathrm{Cm}_{\hat{s}r's} m_{\hat{s}r's} + \sum \mathrm{Crcp}_{\hat{r}} \hat{x}_{r\hat{r}} + \sum \mathrm{Ctran}_{jrr'} t_{jrr'} \tag{12}$$

Cost of purchased petroleum products imported from the world supply curve

$$+\sum \mathrm{Cpim}_{ps} \hat{\imath}_{ps} \tag{13}$$

Transport cost of U.S. petroleum product imports and exports

$$+\sum \mathrm{Cpim}_{pr} i_{pr} + \sum \mathrm{Cpex}_{pr} e_{pr} \tag{14}$$

Cost of FBD biodiesel imports

$$+\sum \mathrm{Cbim}_{rs} i_{rs} \tag{15}$$

Cost of RDH renewable diesel imports

$$+\sum \mathrm{Crim}_{rs} j_{rs} \tag{16}$$

Revenue from coproduct sales

$$-\sum \mathrm{Rcp}_{pr} cp_{pr} \tag{17}$$

Revenue from product exports

$$-\sum \mathrm{Rpex}_{ps} e_{ps} \tag{18}$$

Revenue from corn ethanol exports

$$-\sum \mathrm{Rce}_{s} ke_{s} \tag{19}$$

Crude oil-related constraints

Table B-8. Crude oil-related constraints

Constraint description	GAMS cross reference
Crude oil balance	CrudeBalance
Crude oil import limit	CrudeImportLimit
Crude oil export limit	CrudeExportLimit
Crude oil export limit to Sarnia: 393,000 barrels per day	CrudeExportLimit3CAN
World crude oil supply	WorldCrudeSup
Foreign crude oil supply curve	CrudeSupCurveForeign
Limited re-exports of crude oil	ExportDomCrudeOnly

Crude oil balance

The volume of each crude oil type processed in a region is equal to domestic production plus net imports plus net shipments from other regions.

$$\sum_{\hat{p}} A_{\hat{p}c} x_{\hat{p}r} = P_{cr} + \sum_{s} i_{crs} - \sum_{s} e_{crs} + \sum_{r'} (t_{cr'r} - t_{crr'}) \qquad \text{for all } c, r \tag{20}$$

World crude oil supply

Total world supply of all crude oils equals non-U.S. supply plus U.S. production.

$$\sum_{s} w'_s = \sum_{c} \sum_{s} n_{cs} + \sum_{c} \sum_{r} P_{cr} \tag{21}$$

Foreign crude oil supply

Total world consumption of each crude oil type equals non-U.S. consumption plus net imports to the United States.

$$\sum_{s} w_{cs} = \sum_{s} n_{cs} + \sum_{r} \sum_{s} i_{crs} - \sum_{r} \sum_{s} e_{crs} \qquad \text{for all } c \tag{22}$$

Crude oil import limit

Total crude oil imports are limited on each step of the international crude oil supply curve.

$$\sum_{c} i_{crs} \leq UI_{rs} \qquad \text{for all } r, s \tag{23}$$

Crude oil export limit

Total crude oil exports are limited on each step of the international crude oil demand curve.

$$\sum_{c} e_{crs} \leq UE_{rs} \qquad \text{for all } r, s \tag{24}$$

Crude oil export limit to Sarnia

API>40 crude oil exports to Sarnia, Canada, from LFMM region 3 are limited to 393,000 b/d.

$$\sum_{c} e_{crs} \leq 393 \qquad \text{for all } r, s \tag{25}$$

Limit re-exports of crude oil

Any U.S. crude oil exports from a particular region must be from domestic production in that region or shipments from a different U.S. region, rather than immediate re-exports of imported crude oil.

$$P_{cr} + \sum_{r'} t_{cr'r} \leq \sum_{s} e_{crs} \qquad \text{for all } c, r \tag{26}$$

Product imports and exports

Table B-9. Product import and export constraints

Constraint description	GAMS cross reference
Product import balance	ProdImpBalance
Product import supply curve	ProdImpSupCurve
Product import transportation limit	ImpTranLimit
Product export balance	ProdExpBalance
Product export demand curve	ProdExpSupCurve
Product export transportation limit	ExpTranLimit

Product export balance

The total exports of a product to an international region equals the sum of exports from all domestic regions.

$$e_{pr} = \sum_{r'} t_{prr'} \qquad \text{for all } p, r \tag{27}$$

Product export demand curve

The total exports of a product to an international region equals the sum of exports over all steps of the demand curve.

$$\sum_{r} t_{prr'} = \sum_{s} \hat{e}_{pr's} \qquad \text{for all } p, r' \tag{28}$$

Product export transportation limit

$$\sum_{p} t_{prr'} \leq UE_{rr'} \qquad \text{for all } r, r' \tag{29}$$

Product import balance

The total imports of a product to a domestic region equals the sum of imports to the region from all international regions.

$$i_{pr} = \sum_{r'} t_{pr'r} \qquad \text{for all } p, r \tag{30}$$

Product import supply curve

The total imports of a product from an international region equals the sum of imports from the region over all steps of the supply curve.

$$\sum_{r} t_{pr'r} = \sum_{s} \hat{\imath}_{pr's} \qquad \text{for all } p, r' \tag{31}$$

Import transportation limit

$$\sum_{p} t_{pr'r} \leq UI_{r'r} \qquad \text{for all } r, r' \tag{32}$$

Ethanol trade flow

Table B-10. Ethanol trade constraints

Constraint description	GAMS cross reference
Balance on corn ethanol exports from United States	EthExpUSBal
Balance on advance ethanol imports to United States	EthImpUSBal

Balance on corn ethanol exports from the United States

The sum of corn ethanol exported from the United States is equal to total foreign demand for corn ethanol from the United States.

$$\sum_{r} e_{jr} = \sum_{s} ke_{s} \qquad where\ j = corn\ ethanol \tag{33}$$

Balance on advanced ethanol imports to the United States

Total foreign supply of sugar cane (advanced) ethanol on all steps of the supply curve is equal to the sum of sugar cane ethanol imported to the United States.

$$\sum_{s} ki_{s} = \sum_{r} i_{jr} \qquad \text{where } j = \text{sugar cane (advanced)ethanol} \tag{34}$$

Ethanol flows

Table B-11. Ethanol flow constraints

Constraint description	GAMS cross reference
Ethanol balance	EthBalance

Ethanol balance

The total volume of ethanol produced in a region plus net imports plus net shipments from other domestic regions is equal to the total amount blended into finished products (gasoline and E85).

$$\sum_{\hat{p}} A_{\hat{p}j} x_{\hat{p}r} + \left(i_{jr} - e_{jr}\right) + \sum_{r'} \left(t_{jr'r} - t_{jrr'}\right) = \sum_{\hat{r}} y_{jr\hat{r}} \qquad \text{for all } r, j \in E \tag{35}$$

Refinery input streams (non-crude oil)

Table B-12. Refinery input stream constraints

Constraint description	GAMS cross reference
Refinery input balance	RefInpBalance
Refinery purchase balance	RefPurchBal
Refinery balance of coal and bio streams	BioRefRegBal, CoalRefRegBal
Supply balance of coal and bio streams	BioBalance, CoalDemBalance, CoalSupBalance
FBD biodiesel balance	BiodieselBalance
RDH renewable diesel balance	RenewDieselBalance
Coal emissions (optional)	SO2EmisBal, HGEmisBal

Refinery input balance

Refinery input streams that are purchased in a region must be consumed by a refinery process or used in recipe-blending or specification-blending in that region.

$$b_{\hat{s}r} = \sum_{\hat{p}} A_{\hat{p}\hat{s}} x_{\hat{p}r} + \sum_{\hat{r}} y_{\hat{s}r\hat{r}} + \sum_{p} z_{\hat{s}pr} \qquad \text{for all } r, \hat{s} \in \text{InputStream} \tag{36}$$

Refinery purchase balance

The total amount of a purchased refinery input includes the amount purchased on all steps of a domestic supply curve plus net imports.

$$b_{\hat{s}r} = \sum_{s} d_{\hat{s}rs} + i_{\hat{s}r} - e_{\hat{s}r} \qquad \text{for all } r, \hat{s} \tag{37}$$

Refinery balance of bio streams

$$\sum_{r'} \widehat{m}_{\hat{s}r'r} \geq \sum_{\hat{p}} A_{\hat{p}\hat{s}} x_{\hat{p}r} \qquad \text{for all } \hat{s}, r \tag{38}$$

Supply balance of bio streams

$$\sum_{s} m_{\hat{s}r's} = G_{\hat{s}r'} + \sum_{r} \widehat{m}_{\hat{s}r'r} \qquad \text{for all } r', \hat{s} \tag{39}$$

FBD biodiesel balance

$$i_r = \sum_{s} i_{rs} \qquad \text{for all } r \tag{40}$$

RDH renewable diesel balance

$$j_r = \sum_{s} j_{rs} \qquad \text{for all } r \tag{41}$$

Coal emissions

$$f_{\hat{e}r} \geq \sum_{\hat{s}} \sum_{r'} H_{\hat{e}r\hat{s}} \widehat{m}_{\hat{s}rr'} \qquad \text{for all } \hat{e}, r \tag{42}$$

Miscellaneous constraints

Table B-13. Miscellaneous constraints

Constraint description	GAMS cross reference
Utility balance	UtilBalance
Stream balance	StreamBalance
Capacity balance	CapacityBalance
Limit regional growth in ADU condensers (LTE)	MaxLTE
Limit national growth in new technologies	RestrictGrowth
Specification-blend property—maximum	GasSpecQualMax, DistSpecQualMax, ResidSpecQualMax
Specification-blend property—minimum	GasSpecQualMin, DistSpecQualMin, ResideSpecQualMin
Specification-blend balance	GasSpecBalance, DistSpecBalance, ResidSpecBalance
Recipe balance	RecipeBalance
Recipe transfer	RecipeTransfer, RecipeBPTransfer
Interregional transport	REFtoREFTran
Combined recipe-product supply	CombineSupply
Demand satisfaction	RecipeDemands,RecipeEndBal, NGLDmd, NGLEndBal, TotProdTran,REFtoCDTran,REFtoCDCap, REFtoREFCapMB
Maximum E15	E15Max
CO_2 demand balance	OGSM_CO2_Demand
LFMM CO_2 carbon capture and sequestration (CCS) balance	CO2CCSBalance

Utility balance

$$a_{ur} = \sum_{\hat{p}} A_{\hat{p}u} x_{\hat{p}r} \qquad \text{for all } r, u \tag{43}$$

Stream balance

Intermediate streams that are produced in a region, plus net imports, and that are not otherwise consumed in a refinery process must be used in recipe-blending or specification-blending in that region.

$$\sum_{\hat{p}} A_{\hat{p}\hat{s}} x_{\hat{p}r} + i_{\hat{s}r} - e_{\hat{s}r} = \sum_{\hat{r}} y_{\hat{s}r\hat{r}} + \sum_{p} z_{\hat{s}pr} \qquad \text{for all r}, \hat{s} \in \text{IntStream} \qquad (44)$$

Capacity balance

Period 1

$$x_{\hat{p}r} \leq E_{\hat{p}r} \qquad \text{for all } \hat{p}, r \qquad (45)$$

Periods 2 and 3

$$x_{\hat{p}r} \leq E_{\hat{p}r} + \hat{E}_{\hat{p}r} \qquad \text{for all } \hat{p}, r \qquad (46)$$

Limit regional growth in ADU condensers (LTE), Periods 2 and 3 only

For ADU condensers, regional expansion is limited to regional-specific $maxBld_r$ every model year.

$$\hat{E}_{\hat{p}r} \leq maxBld \text{ for all } r, \hat{p} = LTE \qquad (47)$$

Limit national growth in new technologies, Periods 2 and 3 only

For each new technology, total U.S. expansion is limited to maxBld every model year.

$$\sum_{r} \hat{E}_{\hat{p}r} \quad \leq maxBld \qquad \text{for all } \hat{p} = new\ tech \qquad (48)$$

Specification-blend property—maximum

For every specification-product property subject to a maximum level, the volume-weighted property of all streams specification-blended into that specification-product may not exceed the maximum level.

$$\sum_{\hat{s}} \hat{P}_{q\hat{s}} z_{\hat{s}pr} \leq \sum_{\hat{s}} \hat{P}^{max}_{qp} z_{\hat{s}pr} \qquad \text{for all } q, r, \qquad p \in \text{SpecProd} \qquad (49)$$

Specification-blend property—minimum

For every specification-product property subject to a minimum level, the volume-weighted property of all streams specification-blended into that specification-product may not be less than the minimum level.

$$\sum_{\hat{s}} \hat{P}_{q\hat{s}} z_{\hat{s}pr} \geq \sum_{\hat{s}} \hat{P}^{min}_{qp} z_{\hat{s}pr} \qquad \text{for all } q, r, \qquad p \in \text{SpecProd} \qquad (50)$$

Specification-blend balance

All specification-blended products must eventually be used in recipe-blending.

$$\sum_{\hat{s}} z_{\hat{s}pr} = \sum_{\hat{r}} y_{pr\hat{r}} \qquad \text{for all } r, p \in \text{SpecProd} \qquad (51)$$

Recipe balance

$$y_{\hat{s}r\hat{r}} = R_{\hat{s}\hat{r}}\hat{x}_{r\hat{r}} \qquad \text{for all } \hat{s}, r, \hat{r} \tag{52}$$

Recipe transfer

$$\check{x}_{rp} = \sum_{\hat{r}} R_{\hat{s}\hat{r}}\hat{x}_{r\hat{r}} \qquad \text{for all } \ r, \hat{s} = p \in \text{RecipeProd} \tag{53}$$

Interregional transport

$$\sum_{\hat{s}} t_{\hat{s}rr'} \leq T_{mrr'} \qquad \text{for all } \ r, r' \tag{54}$$

Combine recipe-product supply

$$h_{pr} = \check{x}_{rp} + i_{pr} - e_{pr} + \sum_{r'}\left(t_{pr'r} - t_{prr'}\right) \qquad \text{for all } r, p \in \text{RecipeProd} \tag{55}$$

Demand satisfaction

$$h_{pr} = D_{pr} \qquad \text{for all } r, \qquad p \in \text{RecipeProd} \tag{56}$$

Maximum E15

The fraction of the total motor gasoline market that can be E15 is subject to an exogenous maximum value. This value changes over time, but the year subscript is suppressed in the equation.

$$\sum_{r} h_{E15,r} \leq MaxE15frac * \sum_{\substack{p\in \\ \text{Gasoline}}} \sum_{r} h_{pr} \tag{57}$$

CO_2 demand balance

Carbon dioxide available to be captured at ethanol facilities is represented. 45Q tax credit representation is housed in the Carbon Capture Allocation Transportation Supply (CCATS) module. For the current AEO, the representation of ethanol retrofits with carbon capture is done exogenously.

Policy constraints

Table B-14. Policy constraints

Constraint description	GAMS cross reference
RFS requirements	RFSConstraintsPRD, RFSConstraintsRQM
LCFS requirements	LCFS_Biofuel, LCFS_Petroleum, LCFS_LandfillGasConstr
AB32 requirements	AB32_Constraint

RFS requirements

The total amount of credits earned from production of RFS-compliant biofuels must be at least as great as the adjusted RFS target.

$$\sum_{r}\sum_{\hat{p}}\sum_{\hat{s}} RFSScore_{k\hat{s}}A_{\hat{p}\hat{s}}x_{\hat{p}r} \geq RFSTarget_{k} \qquad \text{for all } k \in \text{RFSCategory}, A < 0 \tag{58}$$

LCFS requirements

The total carbon intensity of motor fuels (gasoline and diesel) sold in California must be lower than the (adjusted) target carbon intensity. This factor is represented by two constraints, one for each recipe product (p): gasoline and diesel. The difference in carbon intensity of each recipe stream and its recipe product target must be less than or equal to zero. Landfill gas (lg) is counted toward either (not both) recipe product targets. Thus, a balance row for landfill gas prevents the total available from being exceeded. The LFMM LP includes a safety valve, not shown here, that allows purchase of carbon credits to ensure that the LP is feasible.

$$\sum_{\hat{r}} LCFSfactor_{p\hat{r}}\ h_{pr} + LCFSfactor_{p,lg}\ lg_{pr} \leq 0 \qquad \text{for } r = \text{California}, p \in \text{RecipeProd} \quad (59)$$

$$\text{(gasoline and diesel)}$$

$$\sum_{p} lg_{pr} = Landfill\ gas\ total_{r} \qquad \text{for } r = \text{California} \quad (60)$$

Appendix C. Bibliography

The LFMM mid-term model development web page includes a section on:

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- Needs Assessment and Model Development Process (May 10, 2009; November 24, 2009
- Technical Workshop (September 30, 2009)
- Component Design Report (October 16, 2010)

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Additional citations are in Appendix A, the AEO2022 Assumptions Document, and the LFMM Component Design Report.

Appendix D. Model Abstract

Model name

Liquid Fuels Market Module

Model acronym

LFMM

Description

The Liquid Fuels Market Module (LFMM) is a simulation of the U.S. liquid fuels industry. The core of the model is a linear programming optimization that ensures a rational economic simulation of decisions of feedstock sourcing, resource allocation, and the calculation of a marginal price basis for the petroleum products. The model accounts for more than 20 refined petroleum products that are manufactured, imported, and marketed. These products include specification-blended and recipe-blended petroleum products, as well as coproducts, unfinished products, and by-products. The LFMM models domestic liquid fuels production activities and the marketing of petroleum products to consumption regions.

Capacity-limited transportation systems are included to represent existing intra-U.S. crude oil and petroleum product shipments (LPG, clean, dirty) by pipeline, marine tanker, barge, and truck/rail tankers. The export and import of crude oil and refined products is also simulated. All crude oil and petroleum product imports are purchased in accordance with import supply curves. Crude oil exports are allowed and are connected to the world crude oil supply curves. Product exports are valued by individual export demand curves.

Most of the LFMM is written in GAMS, but some data processing is done in Fortran.

Purpose of the model

The purpose of the LFMM is to project petroleum product prices, refining activities, and movements of petroleum across U.S. borders and among domestic regions within the National Energy Modeling System (NEMS). In addition, the model contains adequate structure and is sufficiently flexible to examine the impact of a wide variety of petroleum-related issues and policy options. These capabilities allow for understanding of the petroleum refining and marketing industry as well as determining the effects of certain policies and regulations.

The LFMM projects sources of supply including feedstocks to be processed, product imports and exports for meeting petroleum product demand. The sources of supply include crude oil, both domestic and imported; other inputs including alcohols and ethers and renewable feedstocks; HGL imports; petroleum product imports; and refinery processing gain. In addition, the LFMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the census division (CD) level and much of the refining activity information is at the PADD (Petroleum Administration for Defense District) and sub-PADD level.

Most recent model update

This documentation describes the March 2025 version used to develop projections for AEO2025.

Main model

The LFMM is a component of the National Energy Modeling System (NEMS).

Model interfaces

The LFMM receives information from the International Energy Module, Natural Gas Market Module, Hydrocarbon Supply Module, Renewable Fuels Module, Electricity Market Module, Hydrogen Market Module, and Carbon Capture, Allocation, Transportation, and Sequestration Module, as well as the Residential, Commercial, Industrial, and Transportation Demand Modules. The LFMM also delivers information to each of the modules listed above plus the Macroeconomic Module within NEMS.

Documentation

U.S. Energy Information Administration, *Liquid Fuels Market Module of the National Energy Modeling System: Model Documentation 2025*, July 2025.

Archive media and installation manual

Archived as part of the NEMS AEO2025 production runs.

Energy system described

Petroleum refining industry, non-petroleum liquid fuels industry, and refined products market.

Coverage

Geographic:

- 13 domestic crude oil production regions
  - East
  - Gulf Coast
  - Mid-Continent
  - Southwest
  - Rocky Mountain
  - Northern Great Plains
  - West Coast
  - Atlantic Offshore
  - Gulf Offshore
  - Pacific Offshore
  - Alaska South
  - Alaska North
  - Alaska Offshore
- 8 domestic refining regions
  - PADD I
  - PADD II Inland
  - PADD II Lakes
  - PADD III Gulf Coast
  - PADD III Inland
  - PADD IV

- PADD V California
- PADD V Other

- 9 market regions
- 9 census divisions
    - New England
    - Middle Atlantic
    - East North Central
    - West North Central
    - South Atlantic
    - East South Central
    - West South Central
    - Mountain
    - Pacific
- 1 international refining region comprising eastern Canada and the Caribbean
- 1 *rest of world* crude oil and petroleum product supply region

Time unit and frequency: annual, 2026 through 2050.

Products:

Asphalt/road oil	Low-sulfur diesel
Biodiesel	Low-sulfur residual fuel oil
Catalyst coke (burned)	Marketable coke
Conventional high oxygen motor gasoline	Other biomass-derived liquids
Conventional motor gasoline	Other petroleum products
Distillate fuel oil	Petrochemical feedstocks
E85	Renewable diesel
Ethanol (undenatured)	Reformulated high oxygen motor gasoline
HGL	Reformulated motor gasoline
High-sulfur residual fuel oil	Still gas
Jet fuel	Ultra-low sulfur diesel

Production processes:

ACU	Atmospheric crude distillation unit
AET	Advanced ethanol (non-cellulosic)
ALK	Alkylation
ARP	Aromatics plant
BPU	Pyrolysis
BSA	Benzene saturation
C4I	Butane isomerization
CGN	Power generation and cogeneration

CLE	Cellulosic ethanol
CPL	Catalytic polymerization
CSU	Condensate splitter
DC4	Debutanization
DC5	Fluid catalytic cracking (FCC) naphtha depentanizer
DDA	Distillate dearomatizer
DDS	ULSD hydrotreater
EDH	Corn ethanol—dry mill, high efficiency
EDM	Corn ethanol—dry mill
ETHCCS	Ethanol retrofit pseudo-unit
FBD	FAME biodiesel
FCC	Fluid catalytic cracker
FDS	FCC feed hydrotreater
FGS	FCC naphtha fractionator
FUM	Fuel psuedo-unit
GDS	FCC naphtha hydrotreater
GDT	Renewable diesel hydrotreater
HCD	Hydrocracker
IBA	Isobutanol pseudo-unit
KRD	Delayed coker
KWG	Electricity generation
LNS	Light naphtha splitter
LTE	Light ends condenser on ADU
LUB	Lubricant production
NDS	Naphtha hydrotreater
PHI	Once-through isomerization
RCR	Continuous cyclic reformer
RGN	FCC catalyst regenerator
RSR	Semi-regenerative reformer
SAF	Sustainable aviation fuel
SDA	Solvent deasphalter
SEW	Corn ethanol—wet mill
SGP	Saturated gas plant
STG	Steam production
SUL	Sulfur plant
TRI	Total recycle isomerization
TRS	Stream transfer pseudo-unit
UGP	Unsaturated gas plant
VCU	Vacuum distillation unit

Crude oil: 11 crude oils that vary by API gravity and sulfur content.

Transportation modes: Jones Act dirty marine tanker, Jones Act clean marine tanker, LPG marine tanker, import tankers, clean barge, dirty barge, LPG pipeline, clean pipeline, dirty pipeline, rail/truck tankers. These modes cover all significant U.S. links.

Modeling features

Model structure: GAMS and Fortran

Model technique: Optimization of linear programming representation of refinery processing and non-petroleum liquid fuels production and transportation that relates the various economic parameters and structural capabilities with resource constraints to produce the required product at minimum cost, thereby producing the marginal product prices in a manner that accounts for the major factors applicable in a market economy.

Special features: Choice of imports, exports, or domestic production of products is modeled; capacity expansion of conversion units is determined endogenously; product prices include fixed, environmental, and policy-related costs.

Non-DOE input sources

Information Resources Inc. (IRI), National Petroleum Council, ICF Resources, Oil and Gas Journal, U.S. EPA gasoline properties survey, Jacobs Consulting Refinery Technology database, OnLocation, Inc., and its subcontractors.

DOE input sources

Forms:

EIA-14	*Refiners' Monthly Cost Report*
EIA-182	*Domestic Crude Oil First Purchase Report*
EIA-810	*Monthly Refinery Report*
EIA-812	*Monthly Product Pipeline Report*
EIA-813	*Monthly Crude Oil Report*
EIA-814	*Monthly Imports Report*
EIA-815	*Monthly Bulk Terminal and Blender Report [EIA-811 before 2009]*
EIA-816	*Monthly Natural Gas Liquids Report*
EIA-817	*Monthly Tanker and Barge Movements Report*
EIA-819	*Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene*
EIA-820	*Annual Refinery Report*
EIA-826	*Monthly Electric Sales and Revenue with State Distributions Report*
EIA-856	*Monthly Foreign Crude Oil Acquisition Report*
EIA-914	*Monthly Crude Oil and Lease Condensate, and Natural Gas Production Report*
EIA-923	*Power Plant Operations Report [FERC-423 before 2009]*

In addition to the above, EIA uses information from several of its publications:

- Petroleum Supply Annual
- Petroleum Supply Monthly
- Petroleum Marketing Annual (prior to 2010)

- Petroleum Marketing Monthly
- Fuel Oil and Kerosene Sales (prior to 2021)
- Natural Gas Annual
- Natural Gas Monthly
- Annual Energy Review (prior to 2012)
- Monthly Energy Review
- State Energy Data Report
- State Energy Price and Expenditure Report

Independent expert reviews conducted

None.

Independent reviews of the predecessor to the LFMM, the Petroleum Market Module (PMM), were conducted by:

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N. Yamaguchi, Trans-Energy Research Associates, Inc., November 1997.
J. Urbanchuk, AUS Consultants, May 1998.
Ray Ory, independent consultant, June 2003
Terry Higgins, International Fuel Quality Center, June 2003
Fred Joutz and Inderjit Kundra, George Washington University, and Statistics and Methods Group of EIA, December 2003
Julian Silk, Robert P. Trost, Michael Ye, and Inderjit Kundra, Statistics and Methods Group of EIA, November 2005
Michael Ye, Robert P. Trost, Michael Ye, Ramesh Dandekar, and Inderjit Kundra, Statistics and Methods Group of EIA, April 2009

Status of evaluation efforts by sponsor

None.

Appendix E. Data Assumptions

EIA survey forms

Form EIA-14, Refiners' Monthly Cost Report
Form EIA-14, *Refiners' Monthly Cost Report*, is used to collect summary data that permit EIA to provide the government and the public certain cost and price statistics on the U.S. petroleum industry. The data appear on EIA's website and in the EIA publications, *Petroleum Marketing Monthly*, *Monthly Energy Review*, and *Annual Energy Review*.

Form EIA-182, Domestic Crude Oil First Purchase Report
Form EIA-182, *Domestic Crude Oil First Purchase Report*, is designed to collect data on both the average cost and volume associated with the physical and financial transfer of domestic crude oil off the property on which it was produced. The monthly reported data represent the initial market value and volume of domestic crude oil production. The primary statistic is the weighted average wellhead price for selected domestic crude oil streams aggregated by state. First purchase volumes are also used in generating estimates of domestic crude oil production. Because this report is statistical, definitions vary unavoidably from those of some state agencies whose purpose is strictly fiscal or regulatory (see Definitions). The U.S. Department of Energy (DOE) uses the data in reviewing the supply, demand, quality, and price changes of crude oil. We publish the average wellhead prices in the *Petroleum Marketing Monthly*, the *Monthly Energy Review*, the *Annual Energy Review*, and the *Oil and Gas Lease Equipment and Operating Costs 1994–2009*.

Form EIA-810, Monthly Refinery Report
Form EIA-810, *Monthly Refinery Report*, is used to collect data on the operations of all petroleum refineries located in the 50 states, District of Columbia, Puerto Rico, the Virgin Islands, Guam, and other U.S. possessions. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-812, Monthly Product Pipeline Report
Form EIA-812, *Monthly Product Pipeline Report*, is used to collect data on end-of-month stocks and movements of petroleum products transported by pipeline. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-813, Monthly Crude Oil Report
Form EIA-813, *Monthly Crude Oil Report*, is used to collect data on end-of-month stocks of crude oil and movements of crude oil by pipeline. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-814, Monthly Imports Report
Form EIA-814, *Monthly Imports Report*, is used to collect data on imports of crude oil and petroleum products. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-815, Monthly Bulk Terminal and Blender Report
Form EIA-815, *Monthly Bulk Terminal and Blender Report*, is used to collect data on end-of-month stocks of petroleum products. A summary of the data appears on EIA's website and in numerous government publications. Predecessor survey, EIA-811, Monthly Bulk Terminal Report, was terminated after 2009.

Form EIA-816, Monthly Natural Gas Liquids Report

Form EIA-816, *Monthly Natural Gas Liquids Report*, is used to collect data on supply and disposition of natural gas liquids including stocks, receipts, production and shipments. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-817, Monthly Tanker and Barge Movements Report

Form EIA-817, *Monthly Tanker and Barge Movements Report*, is used to collect data on the movement of crude oil and petroleum products. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-819, Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene

Form EIA-819, *Monthly Report of Biofuels, Fuels from Non-Biogenic Wastes, Fuel Oxygenates, Isooctane, and Isooctene*, is used to collect data on the production capacity of fuel alcohol, biodiesel, renewable diesel, heating oil, jet fuel naphtha, other renewable fuels, isooctane, isooctane, and fuel oxygenates. Data collected include information regarding the balance between the supply (beginning stocks, receipts, and production) and disposition (inputs, shipments, plant use and losses, and ending stocks) of biofuels and oxygenates at the plant during the report month. The data appear on EIA's website and in numerous government publications.

Form EIA-820, Annual Refinery Report

Form EIA-820, *Annual Refinery Report*, is used to collect data on current and projected capacities of all operable petroleum refineries. The data appear on EIA's website and in numerous government publications.

Form EIA-826, Monthly Electric Utility Sales and Revenue Report with State Distributions

Form EIA-826, *Monthly Electric Utility Sales and Revenue Report with State Distributions*, collects information from electric utilities, energy service providers, and distribution companies that sell or deliver electric power to end users. Data collected on this form include sales and revenue for all end-use sectors (residential, commercial, industrial, and transportation). The data from this form appear in *Electric Power Monthly*, *Monthly Energy Review*, and *Annual Energy Review*. We use the data collected on this form to monitor the status and trends of the electric power industry and to inform our projections of the future of the industry.

Form EIA-856, Monthly Foreign Crude Oil Acquisition Report

Form EIA-856*, Monthly Foreign Crude Oil Acquisition Report*, is used to collect data on the cost and quantities of foreign crude oil (by country of origin) acquired for importation into the United States, including U.S. territories and possessions. DOE, the International Energy Agency (IEA), other federal agencies, and industry analysts use the data for forecasting and analytical purposes.

Form EIA-914, Monthly Crude Oil and Lease Condensate, and Natural Gas Production Report

Form EIA-914*, Monthly Crude Oil and Lease Condensate, and Natural Gas Production Report*, collects data directly from crude oil and natural gas producers in 15 states, the Federal Offshore Gulf of Mexico (GOM), and other states. The survey uses the reported data to estimate total production for those areas and the United States. A summary of the data appears on EIA's website and in numerous government publications.

Form EIA-923, Power Plant Operations Report

Form EIA-923, *Power Plant Operations Report*, collects information from electric power plants and combined-heat-and-power (CHP) plants in the United States. Data collected on this form include electric power generation, fuel consumption, fossil fuel stocks, delivered fossil fuel cost, combustion by-products, operational cooling water data, and operational data for nitrogen oxides, sulfur dioxide, and particulate matter control equipment. We use these data to monitor the status and trends of the electric power industry.

Distribution cost data

We incorporate costs relating to distributing petroleum products to end users by adding fixed transportation markups to the wholesale prices, which include the variable and fixed refinery costs. We estimate transportation markups for petroleum products as the average annual difference between retail and wholesale prices from 1990 through 2022.[2] The differences are based on wholesale prices in the producing census division and end-use prices (which do not include taxes) in the consuming census division. See Appendix F for a discussion of programs and input files used in estimating these markups.

Tax data

In the LFMM, state and federal taxes are added to the prices of gasoline, distillate fuel, liquefied petroleum gas (LPG), jet fuel, ethanol, and methanol in the transportation sector. State taxes are assumed to keep pace with inflation (held constant in real terms), and federal taxes are held at current nominal levels (deflated in each projection year).[3] The federal tax assumption reflects the overall projection assumption of current laws and legislation. The assumption that state taxes will increase at the rate of inflation reflects an implied need for additional highway revenues as driving increases. We add an additional 1% per gallon of the gasoline price to the state gasoline taxes to estimate local taxes.

State taxes are added as census division weighted averages, which are based on tax data available as of 2023. State and federal taxes for gasoline, transportation distillate, and jet fuel are based on data from the Federal Highway Administration, but they are modified to include other known changes to state taxes. The quality of the state-level tax data is unknown but deemed reliable. The local tax estimate of 1% per gallon of gasoline price is reasonable given that a comparison of two EIA data series, one including local taxes and one not, revealed a gasoline price difference of 1.6 cents per gallon. Federal taxes, which were adjusted in January of 2001, are widely published and deemed highly reliable.

See Appendix G for a description of programs and input files used to calculate historical taxes and estimate taxes used in the price projections.

Critical variables

The LFMM contains numerous variables and parameters. Some variables affect model results more than others do. The following is a list of variables that we believe have a high degree of influence on LFMM results. We provide it to help users understand the critical factors affecting the LFMM.

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[2] Transportation markups for kerosene are based on the difference between end-user kerosene prices and wholesale distillate prices. Markups are estimated based on the most recent available price data.

[3] Refer to Stacy MacIntyre, *Motor Fuels Tax Trends and Assumptions, Issues in Midterm Analysis and Forecasting 1998*, DOE/EIA-0607(98), (Washington, DC, July 1998).

- World oil price
- Product demands
- Import crude oil supply curves
- Import and export product supply and demand curves
- Domestic crude oil production
- Prices and available supplies of renewable liquid fuels and their feedstocks
- Investment cost for capacity expansion
- Market shares for gasoline and distillate types
- NGPL supply volumes

Other modules provide most of these variables in the NEMS system. The investment cost and market share data are developed offline and read in to the LFMM.

Appendix F. Estimation Methodologies

Refinery investment recovery thresholds

The process plant cost function (PCF) represents the threshold for expansion investment decisions. The PCF considers actual cash flows associated with the operation of the individual process plants within the refinery, as well as cash flows associated with capital for the construction of new plants. It includes terms for capital-related financial charges (CFC), fixed operating costs (FOC), and other variable operating costs (OVC):

$$PCF = \sum_i (CFC_i + FOC_i + OVC_i), \tag{1}$$

where i indexes the individual process units that make up the petroleum refinery, such as the atmospheric crude oil distillation unit, fluid catalytic cracking unit, etc.

In the LFMM, the OVC are defined directly from input data (so these costs will not be addressed in this section), while the CFC and the FOC are derived using a series of process investment cost equations. The methodologies used to calculate these cost components are presented below.

Capital-related financial charges (CFC)

The CFC equation includes an annual capital recovery charge (ACR) minus a depreciation tax credit (DTC):

$$CFC_i = ACR_i - DTC_i. \tag{2}$$

A discounted cash flow calculation is generally used to determine the annual capital charge for any given plant investment. The annual capital recovery charge assumes a discount rate equal to the cost of capital (COC), which includes equity (cost of equity, COE) and interest payments on any loans or other debt instruments used as part of capital project financing (cost of debt, COD). The depreciation of capital equipment is used to determine the depreciation tax credit (DTC). Both the ACR and DTC are estimated on an after-tax basis.

Because the LFMM and other energy projection models employ *notional* representations of U.S. petroleum refineries involving aggregation of data for many individual refineries, the cost-estimating algorithm has been simplified while still capturing all the factors and costs refiners must consider when adding a new processing unit. The methodology draws on the National Petroleum Council (NPC) study[4] and other sources.[5] Some of the steps for the cost estimate are conducted exogenous to NEMS (Step 1 below), either by the analyst in preparing the input data or during input data preprocessing. The individual steps in the plant capital cost estimation algorithm:

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[4] National Petroleum Council, *U.S. Petroleum refining – Meeting Requirements for Cleaner Fuels and Refineries*, Washington, DC, August 1993.

[5] J.H. Gary and G.E. Handwerk, *Petroleum Refining: Technology and Economics*, 4th edition (New York: Marcel Dekker, 2001), Chapters 17 and 18.

1. Estimation of the inside battery limits (ISBL) field cost (done exogenous to NEMS)
2. Estimation of the ISBL field cost for different refinery locations (location factor)
3. Estimation of the outside battery limits (OSBL) field cost (added to ISBL to define total field cost)
4. Estimation of total project cost
5. Estimation of capital-related financial charges
6. Conversion of capital-related charges to a *per-day*, *per-capacity* basis

Step 1 may involve several adjustments that we must make before we input the ISBL field cost into the LFMM. The remaining steps are performed within the LFMM.

Step 1 - Estimation of ISBL field cost

The inside battery limits (ISBL) field costs include the direct cost, such as major equipment, bulk materials, direct labor costs for installation, construction subcontracts, and indirect costs. The ISBL investment cost and labor costs for most of the refinery processing unit types modeled were initially obtained from a study by Bonner and Moore Associates (BMA),[6] and we updated these costs with revised estimates from EnSys Energy and Systems, Inc. (EnSys) in 2017 . We obtained the data for typical unit sizes and stream factors, as well as supplementary investment and labor, from the World Oil Refining, Logistics, and Distribution (WORLD) model.[7] The data used by the LFMM currently represent process plants sited at a generic U.S. Gulf Coast (PADD III) location and are in year 1993 dollars.

Step 2 - Year-dollar and location adjustment to ISBL field costs

We must adjust the ISBL investment cost data to include location factors and correct year-dollars:

- Adjust the ISBL field costs and labor costs for each processing unit (*j*) from 1993 dollars, first to the year-dollar (rptyr) reported by NEMS (for example, 2012 dollars for AEO2014), using the Nelson-Farrar refining-industry cost-inflation indices. Next, use the GDP chain-type price indices provided by the NEMS Macroeconomic Activity Model to convert from report-year dollars to 1987-year dollars used internally by NEMS.

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[6] Bonner & Moore Associates, Inc., *A Capital Expansion Methodology Review of the Department of Energy's Petroleum Market Model*, prepared for the U.S. Department of Energy, Contract No. EI-94-25066 (Houston, TX, July 1994).
[7] EnSys Energy & Systems, Inc., *WORLD Reference Manual*, a reference for use by the analyst and management, prepared for the U.S. Department of Energy, Contract No. DE-AC-01-87FE-61299 (Washington, DC, September 1992).

- Convert the ISBL field costs in 1987 dollars for each processing unit from a PADD III (Gulf Coast) basis (*BM_ISBL*) to costs of the same processing unit for other regions (*ISBL*) by using location multipliers (*INVLOC).* The location multipliers represent differences in material costs between the various PADD regions.

$$ISBL_j = \frac{BM\_ISBL_i * INVLOC_j}{1000} \tag{3}$$

where

i = process unit in PADD III;

l = refining region;

j = process unit i in refining region l;

$ISBL_j$ = ISBL costs for processing unit i in refining region (PADD) l (j), in million 1987 dollars;

BM_ISBL_i = ISBL costs for processing unit i in PADD III, in thousand 1987 dollars; and

$INVLOC_l$ = location multiplier for refining region l.

Location multipliers for refinery construction were developed on a PADD basis using the most recent data available from the U.S. Bureau of Labor Statistics (BLS)[8] and EIA.[9] The development of these multipliers and assumed values for other factors is described elsewhere.[10] The recommended location multipliers for refinery construction are given below:

Table F-1. Location multipliers for refinery construction

Location	Location construction multiplier
PADD I – U.S. East Coast	1.16
PADD II – U.S. Midwest—inland	1.00
PADD II – U.S. Midwest—lakes	1.00
PADD III – U.S. Gulf Coast—gulf	1.00
PADD III – U.S. Gulf Coast—inland	1.00
PADD IV – U.S. Rocky Mountain	1.08
PADD V – U.S. West Coast—California	1.15
PADD V – U.S. West Coast- other	1.15

[8] Wages Data, U.S. Department of Labor, Bureau of Labor Statistics, available on the web at www.bls.gov/bls/blswage.htm.
[9] Refinery Capacity Data, U.S. Department of Energy, U.S. Energy Information Administration, available on the web at www.eia.doe.gov/oil_gas/petroleum/data_ publications/refinery_capacity_data/refcapacity.html.
[10] *A General Cost Estimating Methodology for New Petroleum Refinery Process Capacity,* Appendix D, prepared for the U.S. Department of Energy, National Energy Technology Laboratory, and U.S. Energy Information Administration by John Marano, Ph.D., September 2004.

Step 3 - Estimation of OSBL cost and total field cost

The outside battery limit (OSBL) costs include the cost of cooling water, steam and electric power generation and distribution, fuel oil and fuel gas facilities, water supply, etc. The total field cost (FDC) is the sum of the ISBL and OSBL field costs. The OSBL field cost is estimated as a fraction (OSBLFAC) of the ISBL costs. Thus, the resulting FDC equation is:

$$FDC_j = (1 + OSBLFAC) * ISBL_j \tag{4}$$

where

j = process unit i in refining region l;

FDC_j = total field costs for processing unit in refining region *(j)*, in million 1987 dollars;

$ISBL_j$ = ISBL costs for processing unit in refining region *(j)*, in million 1987 dollars; and

OSBLFAC = OSBL fraction of ISBL costs (assumed to be 0.45 in the LFMM).

Step 4 – Estimation of total project investment

The total project investment (TPI) is the sum of the total field cost (Eq. 4) and other one-time costs (OTC):

$$TPI_j = FDC_j - OTC_j \tag{5}$$

where

j = process unit i in refining region l;

TPI_j = total project investment for processing unit in refining region *(j)*, in million 1987 dollars;

FDC_j = total field costs for processing unit in refining region *(j)*, in million 1987 dollars; and

OTC_j = other one-time costs for processing unit in refining region *(j)*, in million 1987 dollars.

Other one-time costs (OTC) include the contractor’s cost (such as home office costs), the contractor’s fee and a contractor’s contingency, the owner’s cost (such as pre-startup and startup costs), and the owner’s contingency and working capital (WC). The OTCs are estimated as a function of total field costs (FDC), using cost factors (OTCFAC). The corresponding equations are presented below.

$$OTCFAC = PCTENV + PCTCNTG + PCTLND + PCTSPECL + PCTWC \tag{6}$$

where

PCTENV = 0.10, home, office, contractor fee;

PCTCNTG = 0.05, contractor and owner contingency;

PCTLND = 0.00, land (assuming expansion only at existing refinery);

PCTSPECL = 0.05, prepaid royalties, license, start-up costs; and

PCTWC = 0.10, working capital.

thus,

OTCFAC *= 0.30*

and

$$OTC_j = OTCFAC * FDC_j \tag{7}$$

The TPI given above represents the total project investment (cost) for *overnight construction*. The TPI at project completion and startup will be discussed in Step 5 below.

Closely related to the total project investment are the fixed capital investment (FCI) and total depreciable investment (TDI). The FCI is equal to the TPI minus working capital. It is used to estimate capital-related fixed operating costs (discussed later). A default value of 0.10 is assumed for the WC factor (PCTWC):

$$WRKCAP_j = PCTWC * FDC_j \tag{8}$$

and

$$FCI_j = TPI_j - WC_j \tag{9}$$

where

j = process unit *i* in refining region *l*;

WC_j = total working capital for processing unit in refining region *(j),* in million 1987 dollars;

FDC_j = total field costs for processing unit in refining region *(j)*, in million 1987 dollars;

PCTWC = working capital as percent of FDC_j;

FCI_j = fixed capital investment for processing unit in refining region *(j)*, in million 1987 dollars; and

TPI_j = total project investment for processing unit in refining region *(j)*, in million 1987 dollars.

The TDI is equal to the TPI minus the cost of land, interest during construction, and working capital (as discussed in Step 4 below). For construction at an existing refinery site through expansion, as would most likely be the case in the United States, the cost of land can be assumed to be zero, and interests during construction are considered implicitly in the calculation of the capital charge factor (Step 5); thus, TDI is assumed to be about equal to FCI:

$$TDI_j = FCI_j \tag{10}$$

where

j = process unit *i* in refining region *l*;

TDI_j = total depreciable investment for processing unit in refining region *(j)*, in million 1987 dollars; and

FCI_j = fixed capital investment for processing unit in refining region *(j)*, in million 1987 dollars.

Step 5 - Estimation of capital-related financial charges

To determine the economic viability of expanding refinery processing capacity, capital-related financial charges (CFC), which consist of an annual capital recovery charge (ACR) and a depreciation tax credit (DTC), must be estimated from the total project investment (TPI). The ACR is based on the cost of capital (COC) for the corporation that owns the refinery where the project is located.

It is assumed that projects will be financed by both debt and equity and will return the expected interest payments to creditors and the expected dividends to shareholders. Therefore, the after-tax weighted average cost of capital is an appropriate discount rate for evaluating investment opportunities.

Cost of capital

The cost of capital (COC) is the weighted average of the cost of equity (COE) and cost of debt (COD). The COE represents an implied opportunity of financial return to the corporation’s stockholders in the form of dividend payments and stock price appreciation. The COD is the after-tax interest rate, which a company would pay for new, long-term borrowing. In general, the required rate of return for equity investors is much higher than the required rate of return for debt investors (creditors) because the holders of common stock (equity investors) accept all the risks involved in business ownership. The COC is related to COE and COD as follows:

$$COC = X_{eq} \times COE + X_{debt} \times COD(at) \quad (11)$$

and

$$COD(at) = (1 - T_{eff,l}) \times COD(bt) \quad (12)$$

where

X_{eq}, X_{debt} = fractions of equity and debt financing, respectively ($X_{debt} = 1 - X_{eq}$);

$T_{eff,l}$ = effective corporate income tax rate; *l* is for refining region index where all state taxes in that region are averaged to represent a single value; and

at, bt = indices for after-taxes and before-taxes, respectively.

Based on a review of annual financial reports of refining companies or their parent companies, the relative fraction of equity and debt used in the model is set to the capacity-weighted average determined for 2002 ($x_{eq} = 0.60$ and $x_{debt} = 0.40$).

Also, the effective tax rate (T_{eff}) is related to the federal tax rate T_{fed} and state tax rate $T_{state,l}$ as follows:

$$Teff,l = Tstate,l + Tfed \times (1 - Tstate,l) \quad (13)$$

Average state and federal income tax rates were developed on a PADD basis using the most recent tax information available as of January 1, 2004.[11] PADD averages were weighted based on the crude oil processing capacity within the states in each PADD. The resulting state and federal tax rates used in the model are in Table F-2:

Table F-2. State and federal corporate income tax rates

Location	State	Federal
PADD I – U.S. East Coast	9.32%	21%
PADD II – U.S. Midwest	7.38%	21%
PADD III – U.S. Gulf Coast	3.32%	21%
PADD IV – U.S. Rocky Mountain	4.21%	21%
PADD V – U.S. West Coast	6.76%	21%

The pre-tax cost of debt (COD(bt)) will vary based on the proportions of short-term loans and bonds. A Baa average corporate bond rate (MC_RMCORPBAA from the NEMS Macroeconomic Activity Model) is used for COD(bt).

The expected opportunity cost, or cost of equity (COE), for stockholders should be comparable to what could be realized from alternative investments of similar risk. The Capital Asset Pricing Model (CAPM) is

[11] State Corporate Income Tax Rates, available on the web at https://taxfoundation.org/data/all/federal/historical-corporate-tax-rates-brackets/ and at https://taxfoundation.org/data/all/state/state-corporate-income-tax-rates-brackets/

used to compute a cost of equity,[12] which is an implied investor's opportunity cost or the required rate of return of any risky investment. The model is

$$COE = RFR + \beta \times EMRP \quad (14)$$

The COE is computed as a function of three variables: *RFR*, a *risk-free* rate; EMRP, an expected market risk premium; and β, a systematic risk coefficient relative to the stock market (referred to as the *equity beta*). In the model, the risk-free rate is based on 10-year Treasury note rates (MC_RMTCM10Y, provided by the NEMS Macroeconomic Activity Model). The EMRP and β are assumed to be constant. Thus, the EMRP is assumed at 6.75% (7.5% for high-risk and non-petroleum based technologies) based on the expected return on market over the rate of a 10-year Treasury note (risk-free rate); and, the β is set based on the risk level of the processing unit investment (for average risk, β = 0.8; for high-risk and non-petroleum based technologies, β = 1.8).

Annual capital recovery

The annual capital recovery (ACR) is the difference between the total project investment (TPI) and the recoverable investment (RCI), all in terms of present value (e.g., at startup). The TPI estimated in Step 4 is for overnight construction (ONC). In reality, the TPI is spread out through the construction period. Land costs (LC) will occur as a lump-sum payment at the beginning of the project, construction expenses (TPI minus WC minus LC) will be distributed during construction, and working capital (WC) expenses will occur as a lump-sum payment at startup. Thus, the TPI at startup (present value) is determined by discounting the construction expenses (assumed as discrete annual disbursements), adding land costs (as lump payment at beginning of project), and adding working capital (WC):

$$TPI(startup) = F_v(COC,N_{con}) \times LC + F_{v,n}(COC,N_{con}) \times (TPI(ONC) - LC - WC) + WC \quad (15)$$

where

TPI(startup) = total project investment at *startup*, in million 1987 dollars;

TPI(ONC) = total project investment (overnight construction), in million 1987 dollars;

WC = total working capital, in million 1987 dollars;

LC = total land costs, in million 1987 dollars;

F_v = future-value compounding factor for an instantaneous payment made *n* years before the *startup* year;

[12] The capital asset pricing model (CAPM) was introduced by Treynor (1961), Sharpe (1964), and Lintner (1965). It extended portfolio theory to introduce the notions of systematic and specific risk. More description of the model can be found at http://www.riskglossary.com/articles/capital_asset_pricing_model.htm .

$F_{v,n}$ = future-value compounding factor for discrete uniform payments made at the beginning of each year starting *n* years before the *startup* year;

N_{con} = construction time in years before *startup* year; and

COC = cost of capital.

The future-value factors are a function of the number of compounding periods (*n*) and the interest rate assumed for compounding. In this case, *n* equals the construction time in years before startup (N_{con} years), the compounding rate used is the cost of capital (*COC*), and the future value refers to the startup year. The formulae for computing each of the discrete compounding factors are:

$$F_v(COC,N_{con}) = (1 + COC)^{Ncon} \quad (16)$$

$$F_{v,n}(COC,N_{con}) = \left(\sum_{k=1,\ N_{con}} \left((1+ COC)^k \right) \right) / N_{con} \quad (17)$$

The recoverable investment (RCI) includes the value of the land and the working capital (assumed not to depreciate over the life of the project), as well as the salvage value (*SV*) of the used equipment:

$$RCI = LC + WC + SV \quad (MM87\$) \quad (18)$$

The present value of *RCI* is subtracted from the TPI at startup to determine the present value (startup year) of the project investment (*PVI*):

$$PVI(startup) = TPI(startup) - P_v(COC,N_{asset}) * RCI \quad (MM87\$\} \quad (19)$$

where

PVI(startup) = present value of project investment at *startup*, in million 1987 dollars;

RCI = recoverable investment, in million 1987 dollars;

TPI(startup) = total project investment at *startup*, in million 1987 dollars;

P_v = present-value discounting factor for an instantaneous payment made n years (project life) in the future;

N_{asset} = asset's economic life in years after *startup* year; and

COC = cost of capital.

The present-value factor is a function of the number of discounting periods (*n*) and the interest rate used for discounting. In this case, *n* equals the asset's economic life in years N_{asset}, and the discounting rate is the cost of capital *COC*:

$$P_v(COC,N_{asset}) = 1. / ((1.+COC)^{Nasset}) \quad (MM87\$) \quad (20)$$

If the cost of land is assumed to be zero, and the salvage value is equal to dismantling costs, then the *PVI(startup)* can be reduced to:

$$PVI(startup) = F_{v,n}(COC,N_{con}) \times FCI + (1 - P_v(COC,N_{asset}) \times WC) \quad (21)$$

Thus, the annual capital recovery (*ACR*) is given by:

$$ACR(at) = Av\ (COC,Nasset) * PVI(startup) \quad (MM87\$/yr) \quad (22)$$

where

ACR(at) = annual capital recovery, where (*at*) signifies an after-tax basis;

PVI(startup) = present value of project investment at *startup*, in million 1987 dollars;

A_v = uniform-value leveling factor for a periodic payment (annuity) made at the end of each year for (*n*) years in the future;

N_{asset} = asset's economic life in years after *startup* year; and

COC = cost of capital.

The uniform-value factor is a function of the number of periods (*n*) and the interest rate used for discounting, where *n* equals the asset's economic life in years N_{asset} and the discounting rate is the cost of capital *COC*, as defined by:

$$A_v\ (COC,N_{asset}) = (COC *((1.+COC)^{Nasset})) \ / \ (((1.+ COC)^{Nasset}) -1.) \quad (23)$$

A construction period of 2 years and asset life of 20 years are assumed for construction of a new process unit within an existing refinery.

Depreciation tax credit and capital-related financial charges

The depreciation tax credit (DTC) is based on the depreciation schedule for the investment and the total depreciable investment (TDI) (defined in step 4 above). The simplest method (DPM) used for depreciation calculations (and used in the LFMM) is the straight-line method, where the total depreciable investment is depreciated by a uniform annual amount over the tax life of the investment. The following generic equations represent the present value of the TDI (PVDDPM) and the levelized value of the annual depreciation charge (DTC(at)), on an after-tax basis.

$$PVD_{DPM}(startup) = P_{v,DPM}(COC,N_{tax}) * TDI \quad (MM87\$) \quad (24)$$

$$DTC(at) = A_v\ (COC,N_{asset}) * T_{eff} * PVD_{DPM}(startup) \quad (MM87\$/yr) \quad (25)$$

where

$PVD_{DPM}(startup)$ = present value of total depreciable investment, at startup, where *DPM*=straight line depreciation method, in million 1987 dollars;

DTC(at) = annualized depreciation tax credit, where *at*=after tax basis, in million 1987 dollars;

TDI = total depreciable investment, in million 1987 dollars;

T_{eff} = effective combined income tax rate;

$P_{v,DPM}$ = present-value discounting factor for depreciation, which is a function of the number of discounting periods (tax life), and the cost of capital;

A_v = uniform-value leveling factor for a periodic payment (annuity) made at the end of each year for *n* years in the future and an interest rate *r*, where *n* is the asset life and *r* is the cost of capital (*COC*);

at = signifies the depreciation tax credit on an after-tax basis;

N_{asset} = asset's economic life, in years after *startup* year;

N_{tax} = tax life, in years after *startup* year;

COC = cost of capital;

N_{asset} = asset's economic life, in years after *startup* year;

N_{tax} = tax life, in years after *startup* year; and

COC = cost of capital.

If the tax life N_{tax} is assumed to be equal to the asset life N_{asset}, then the leveled depreciation tax credit (DTC) can be represented as follows:

$$DTC(at) = T_{eff} \times TDI \;/\; N_{asset} \quad (MM87\$/yr,\ DPM = SRL,\ Ntax = Nasset) \qquad (26)$$

Finally, the capital-related financial charges (CFC) are set equal to the annual capital recovery (ACR) minus the DTC, after taxes (at) and before taxes (bt):

$$CFC(at) = ACR(at) - DTC(at) \quad (MM87\$/yr) \qquad (27)$$

and,

$$CFC(bt) = CFC(at) / (1 - T_{eff}) \quad (MM87\$/yr) \qquad (28)$$

Step 6 - Convert fixed operating costs to a per-day, per-capacity basis

The annualized capital-related financial charge is converted to a daily charge, and then it is converted to a *per-capacity* basis by dividing the result by the operating capacity of the unit being evaluated. The result is a fixed operation cost on a per-barrel basis. The after-tax CFC is included in the process plant cost function (PCF) presented in equation (1) above.

Refinery unit fixed operating costs

Fixed operating costs (FOC), a component of total product cost, are costs incurred at the plant that do not vary with plant throughput as well as any other costs that cannot be controlled at the plant level. These costs include wages, salaries, and benefits; the cost of maintenance, supplies, and repairs; laboratory charges; insurance, property taxes, and rent; and other refinery overhead. These components can be factored from either the operating labor requirement or the capital cost. The accuracy of this type of estimate should be within ±50%.

Like capital cost estimations, operating cost estimations involve a number of distinct steps. Some of the steps associated with the FOC estimate are conducted exogenous to NEMS (Step 1 below), either by the analyst in preparing the input data or during input data preprocessing. The individual steps in the plant fixed operating cost estimation algorithm are

1. Estimation of the annual cost of direct operating labor
2. Year-dollar and location adjustment for operating labor costs (OLC)
3. Estimation of total labor-related operating costs (LRC)
4. Estimation of capital-related operating costs (CRC)
5. Conversion of fixed operating costs to a *per-barrel* basis

Step 1 involves several adjustments that must be made before input into the LFMM; steps 2–5 are performed within the LFMM.

Step 1. Estimation of direct labor costs

Direct labor costs are inputs to the LFMM and are reported based on a given processing unit size. We initially obtained the operating labor cost data for most of the processing unit types modeled in the LFMM from a study by Bonner and Moore Associates (BMA), and we updated this data annually with revised estimates from EnSys. Ensys obtains the data from the World Oil Refining, Logistics, and Distribution (WORLD) model.[13] The data used by the LFMM currently represent processing plants sited at a generic U.S. Gulf Coast (PADD III) location and are in 1993 dollars.

Step 2. Year-dollar and location adjustment for operating labor costs

Operating labor cost (OLC) data must be adjusted for location and correct year-dollars:

a. The labor costs for each processing unit (i) are adjusted from 1993 dollars, first to the year-dollar (rptyr) reported by NEMS for AEO2014, which is in 2012 dollars, using the Nelson-Farrar refining-industry cost-inflation indices. Then the GDP chain-type price indices provided by the NEMS Macroeconomic Activity Model are used to convert from report-year dollars to 1987 dollars used internally by NEMS. This step defines the interim operating labor cost (BM_LABOR).
b. The 1987 operating labor costs for each processing unit (i) are converted from a PADD III (Gulf Coast) basis into regional (other U.S. PADDs) costs using regional (l) location factors. The location multiplier (LABORLOC) represents differences between labor costs in the various locations and includes adjustments for construction labor productivity.

$$OLC_j = BM\_LABOR_i * LABORLOC_l \qquad (29)$$

[13] EnSys Energy & Systems, Inc., *WORLD Reference Manual*, a reference for use by the analyst and management prepared for the U.S. Department of Energy, Contract No. DE-AC-01-87FE-61299 (Washington, DC, September 1992).

where

i = process unit in PADD III;

l = refining region;

j = process unit i in refining region l;

cd = calendar day;

OLC_j = operating labor costs for processing unit i in refining region (PADD) l (j), in 1987 dollars/cd;

BM_LABOR_i = operating labor costs for processing unit i in PADD III, in 1987 dollars/cd; and

$LABORLOC_l$ = location multiplier for refining region l.

Location multipliers for process unit operating labor were developed on a PADD basis using data available from the U.S. Bureau of Labor Statistics (BLS)[14] and EIA.[15] The recommended location multipliers for process unit construction are in Table F-3.

Table F-3. Location multipliers for refinery operating labor

Location	Operating labor multiplier
PADD I – U.S. East Coast	1.11
PADD II – U.S. Midwest—inland	0.98
PADD II – U.S. Midwest—lakes	0.98
PADD III – U.S. Gulf Coast—gulf	1.00
PADD III – U.S. Gulf Coast—inland	1.00
PADD IV – U.S. Rocky Mountain	1.07
PADD V – U.S. West Coast—California	1.06
PADD V – U.S. West Coast—other	1.06

Step 3. Estimation of labor-related fixed operating costs

Fixed operating costs related to the cost of labor for a processing unit include the salaries and wages of supervisory and other staffing, charges for laboratory services, and payroll benefits and other plant overhead. These labor-related fixed operating costs (LRC) consist of:

$$LRC = OLC + FXOC\_STAFF + FXOC\_OH \qquad (30)$$

where

LRC = labor-related fixed operating cost, in 1987$/cd;

OLC = direct operating labor costs, in 1987$/cd;

[14] Wages Data, U.S. Department of Labor, Bureau of Labor Statistics, www.bls.gov/bls/blswage.htm.
[15] Refinery Capacity Data, U.S. Department of Energy, U.S. Energy Information Administration, https://www.eia.gov/petroleum/refinerycapacity/.

FXOC_STAFF = supervisory and staff fixed operating costs, in 1987$/cd; and

FXOC_OH = benefits and overhead fixed operating costs, in 1987$/cd.

These component FXOC cost terms can be defined as a function of the direct operating labor costs (OLC), with the following relationships: FXOC_STAFF = 0.55*OLC, and FXOC_OH = 0.39*(OLC+FXOC_STAFF). The LRC equation is simplified to the following relationship.

$$LRC = 2.15 * OLC \quad (1987\$/cd) \quad (31)$$

Step 4. Estimation of capital-related fixed operating costs

Capital-related fixed operating costs (CRC) include insurance, local taxes, maintenance, supplies, non-labor-related plant overhead, and environmental operating costs. These costs can be defined as a function of the fixed capital investment (FCI) (defined in equation 9 above). This relationship is expressed by:

$$CRC = M_{CRC} * FCI \quad (87\$/cd) \quad (32)$$

where

M_{CRC} = sum of CRC cost multipliers (defined in Table F-4).

Table F-4. Capital-related fixed operating cost multipliers

Yearly insurance	0.005
Local tax rate	0.01
Yearly maintenance	0.03
Yearly supplies, overhead, etc.	0.005

Step 5. Convert fixed operating costs to a per-capacity basis

On a *per-capacity* basis, the total fixed operating costs (FOC) is the sum of the capital-related operating costs (CRC) and the labor-related operating costs (LRC), divided by the operating capacity of the unit being evaluated.

Natural gas plant liquids

Beginning with AEO2016, the natural gas plant liquids supply to the LFMM is provided by the Hydrocarbon Supply Module (HSM) through the NEMS common variables OGNGPLET (ethane), OGNGPLPR (propane), OGNGPLIS (isobutane), OGNGPLBU (n-butane), OGNGPLPP (pentanes plus). All variables are dimensioned by HSM production districts and model year. See the HSM documentation for more details.

Estimation of distribution costs

We incorporate costs related to distributing petroleum products to end users by adding fixed transportation markups to the wholesale prices (model results) that include the variable and fixed refinery costs. We estimate transportation markups for petroleum products (except gasoline) as the average annual difference between retail and wholesale prices. We hold these markups constant throughout the projection period.

Distribution costs and markups are calculated and estimated on a planned four-year cycle. Every four years, we estimate distribution costs and markups by using State Energy Data System (SEDS) data and available EIA price data by census division, and we assume those results for the projection period.

Sector-level prices provided by EIA's SEDS database typically lag behind current average prices to all sectors by more than two years. Along with algorithms and methods derived from the now retired Refinery Markups Database, we use various calculations EIA API key data to compute suitable proxies for sector-level prices during this time. These derived methods include algorithms filling in missing data by way of API state-level and sectoral price data when available, calculated volume-weighted regional averages, or in some cases (when data are missing completely) price data that are estimated offline and entered manually. Computer programs and data files used to estimate transportation markups are discussed below.

Estimation of taxes

In the LFMM, taxes are added to the prices of gasoline, transportation distillate fuel (diesel), transportation liquefied petroleum gases (LPG), and jet fuel. We also estimate taxes for E85 (transportation ethanol). We develop weighted averages of the most recent available state and federal taxes for each census division (CD) using periodic state survey data collected by the Federation of Tax Administrators.[16] We then aggregate the API Energy data to the CD level in an analyst's spreadsheet using state annual product volumes obtained from EIA[17] to calculate a volume-weighted CD average.

The state taxes are fixed in real terms; the real value of federal taxes declines at the rate of inflation (in other words, federal taxes are fixed in nominal terms). We add an additional 1% of the retail product CD value to the gasoline and diesel taxes to approximate local taxes. Historical tax values are also calculated for gasoline, transportation distillate, jet fuel, and LPG, which we then add to historical end-use prices excluding taxes in order to develop a series with taxes included.

We update federal taxes each projection year by deflating the current value by the rate of inflation for that projection year.

Gasoline specifications

The LFMM models the production and distribution of three different types of gasoline: conventional, reformulated, and CARB (California) gasoline. The following specifications are included in the LFMM to differentiate between conventional and reformulated gasoline blends, according to EPA and California regulations.

- Octane (CON)
- Oxygen content

[16] Motor Fuel Tax Information by State, Federation of Tax Administrators. https://taxadmin.org/motor-fuels-tax-section/
[17] Prime Supplier Sales Volumes, U.S. Department of Energy, U.S. Energy Information Administration. Motor Gasoline: https://www.eia.gov/dnav/pet/pet_cons_prim_a_EPM0_P00_Mgalpd_a.htm. Distillate: https://www.eia.gov/dnav/pet/pet_cons_prim_a_EPDED_K_P00_Mgalpd_a.htm

- Reid vapor pressure (RVP)
- Benzene content (BNZ)
- Aromatic content (ARO)
- Sulfur content (Sulfur)
- Olefin content (OLE)
- The percentage evaporated at 200°F and 300°F (E200 and E300)

In accordance with the EPA Tier-3 regulatory announcement, refiners are required to reduce their average sulfur spec to a maximum of 10ppm beginning in 2017. Beginning in model year 2017, the LFMM reduces the average sulfur spec to 5ppm at the refinery gate to allow for potential contamination during transport. In addition, as a result of a trend in higher octane gasoline, the average octane (CON) increases linearly from 84.9 in 2017 to 87 by 2050 for conventional and from 86.3 to 88.3 for reformulated CARB gasoline.

Table F-5. Gasoline specification

	ARO (max)	BNZ (max)	OLE (max)	RVP (max)	Sulfur (max)	CON (min)	E200 (min)	E300 (min)
Conventional	24.23	0.62	10.80	10.11	22.48[a]	84.9	45.9	81.7
Reformulated	21.00	0.62	10.36	8.80	23.88[a]	84.9	54.0	81.7
California reformulated	23.12	0.58	6.29	7.70	10.00[a]	86.3	42.9	86.3

Source: "EPA Sets Tier 3 Motor Vehicle Emission and Fuel Standards," https://www.epa.gov/fuels-registration-reporting-and-compliance-help/epa-webinar-slides-tier-3-gasoline-sulfur
Note: To account for potential contamination during transport, sulfur spec is set to 5pmm at the refinery gate in the LFMM beginning 2017.
[a] Maximum sulfur spec is reduced to 10ppm beginning in 2017 to meet EPA final ruling.

Estimation of gasoline market shares

Within the LFMM, total gasoline demand is disaggregated into demand for conventional, reformulated, and CARB gasolines by applying assumptions about the annual market shares for each type. Annual assumptions for each region account for the seasonal and city-by-city nature of the regulations. We assume the market shares remain constant during the projection period.

Diesel specifications

The LFMM models three types of distillate fuel oil: heating oil (N2H), low-sulfur diesel (DSL), and ultra-low sulfur diesel (DSU). The two types of diesel fuel differ in their specifications for sulfur, cetane index, aromatics content, and API gravity. DSL reflects a higher sulfur allowance, while DSU reflects the tighter ultra-low sulfur diesel (ULSD) requirement that followed a scheduled phase-in between 2006 and 2014. Currently, all diesel demand in the United States is classified as DSU in the LFMM projection years, and some small amounts of DSL are produced for export.

Table F-6. EPA diesel fuel sulfur limits

Refiner class	June 1, 2006	June 1, 2007	June 1, 2010	June 1, 2012	June 1, 2014 and beyond
Highway diesel					
Non-small refineries		More than 80% 15 parts per million (ppm)		15 ppm	
Small refineries (less than 155,000 barrels per day [b/d]; less than 1,500 employees)				15 ppm	
Nonroad and locomotive/marine (NRLM) diesel					
Non-small refineries nonroad (NR) diesel		500 ppm		15 ppm	
Non-small refineries locomotive/marine (LM) diesel		500 ppm		15 ppm	
Small refineries (less than 155,000 b/d; less than 1,500 employees)		[a]		500 ppm	15 ppm[b]

[a]Northeast and mid-Atlantic requires 500 ppm for all NRLM diesel starting mid-2007.
[b]LM diesel downgrade to 500 ppm is allowed indefinitely, and 15 ppm sulfur is required at refinery gate only.
Source: https://www.epa.gov/diesel-fuel-standards/diesel-fuel-standards-and-rulemakings

According to the ultra-low sulfur diesel (ULSD) regulation finalized in December 2000, ULSD is highway diesel that contains no more than 15 ppm of sulfur at the pump, is limited to a minimum cetane index of 40, and has an aromatics content of 35% by volume. We assume ULSD in California meets California Air Resources Board (CARB) standards that limit maximum sulfur content to 15 ppm (modeled as 10 ppm at the refinery gate to account for potential contamination during transport), minimum cetane index of 53, and maximum aromatics to 10% by volume.[18]

During mid-2004, the U. S. Environmental Protection Agency (EPA) finalized its nonroad diesel rules, which effectively parallel the highway standards but lag by several years in implementation. The specifications and timing of each quality type by refiner class are summarized in Table F-7.

Estimation of diesel market shares

The 2000 ULSD federal regulations and the 2004 nonroad diesel rules were fully implemented after 2014, resulting in three distillate fuels in the marketplace: (a) 15 ppm highway, (b) nonroad locomotive and marine (NRLM) diesel, and (c) high-sulfur heating oil. The LFMM reflects this rule and at the same

[18] https://ww2.arb.ca.gov/sites/default/files/2020-03/dieselspecs.pdf .

time has been calibrated regarding market shares of highway and NRLM diesels, as well as other distillate (including heating oil but excluding jet fuel and kerosene).

Historically, volumes of highway-grade diesel supplied have nearly matched total volumes of transportation distillate sold, although some highway-grade diesel has gone to non-transportation uses such as agriculture and construction. We aggregate diesel fuel by sector and by quality to reflect individual uses for the LFMM. We computed 2007 historical percentages from sector-level data available from the EIA report *Fuel Oil and Kerosene Sales, 2007*.[19] Table F-7 provides an overview of how the categories were grouped.

Table F-7. Screenshot of spreadsheet for estimation of diesel market shares

Distillate consumption

Fuel Oil & Kerosene Sales Total Distillate Consumption by Sector (Thousands of gallons per year; adjusted sales)												
NEMS (SEDS) Sectors	FO & Kero Sectors					In MMBCD						
						1998	1999	2000	2001	2002	2007	
U.S. Total						3.461	3.572	3.732	3.847	3.776	4.197	
Residential						0.367	0.381	0.399	0.409	0.384	0.328	
Commercial						0.199	0.196	0.217	0.229	0.199	0.180	
Industrial						0.147	0.142	0.138	0.152	0.145	0.167	
	Oil Company					0.037	0.038	0.044	0.054	0.054	0.057	
	Farm					0.198	0.189	0.204	0.224	0.206	0.229	
	0.35	road				0.069	0.066	0.071	0.078	0.072	0.080	<- "Road" diesel
	0.65	off-hwy				0.129	0.123	0.132	0.146	0.134	0.149	<- "Off-highway" diesel
	Off-Highway Diesel					0.142	0.140	0.150	0.164	0.144	0.174	
	Total Industrial					**0.524**	**0.508**	**0.535**	**0.594**	**0.549**	**0.627**	
Transportation												
	On-Highway Diesel					1.967	2.091	2.161	2.167	2.238	2.596	
	Railroad					0.185	0.182	0.197	0.193	0.200	0.257	
	Vessel Bunkering					0.139	0.135	0.133	0.137	0.134	0.141	
	Military					0.018	0.019	0.015	0.023	0.021	0.024	
	Total Transportation					**2.308**	**2.427**	**2.507**	**2.519**	**2.593**	**3.018**	
Electric Power						**0.063**	**0.060**	**0.074**	**0.095**	**0.052**	**0.043**	
Diesel used for highway diesel engines & Military						1.985	2.110	2.176	2.189	2.259	2.621	<- tracked separately fr
Rail (locomotive) & Vessel (marine)						0.323	0.317	0.331	0.330	0.334	0.397	<- tracked separately fr
Industrial	**(2007 data)**	60%	**(1998-2002,2007 avg)**	63%	off-highway	0.335	0.320	0.340	0.378	0.348	0.374	<- Nonroad Farm + Off
		27%		23%	highway	0.106	0.108	0.124	0.134	0.123	0.168	<- Industrial Low-Sulfur
		14%		14%	heating oil	0.083	0.080	0.073	0.082	0.078	0.085	<- Industrial: No.1dist +
Residential & Electric HO						0.430	0.441	0.474	0.504	0.435	0.371	<- Residential and Elec
Commercial	**(2007 data)**	38%	**(1998-2002,2007 avg)**	33%	highway	0.063	0.060	0.069	0.079	0.066	0.068	<- Commerical Low-Sul
		11%		14%	off-highway	0.032	0.031	0.031	0.032	0.031	0.019	<- Commerical High-Su
		52%		52%	heating oil	0.104	0.104	0.120	0.118	0.102	0.093	<- Commercial: No.2FC
Highway (Road) Diesel						2.155	2.278	2.369	2.402	2.448	2.856	
Non-Road (Off-Highway) Diesel						0.366	0.351	0.371	0.409	0.379	0.393	
Heating Oil (HO)						0.617	0.626	0.667	0.705	0.615	0.550	
Locomotive/Marine (LM)						0.323	0.317	0.331	0.330	0.334	0.397	

Source: Fuel Oil and Kerosene Sales with Data for 2007, http://www.eia.gov/petroleum/fueloilkerosene/archive/2007/pdf/foksall.pdf .

The ULSD regulation includes a phase-in period under the 80/20 rule that requires the production of 80% ULSD and 20% 500 ppm highway diesel between June 2006 and June 2010 and a 100% requirement

[19] U.S. Department of Energy, U.S. Energy Information Administration, "Fuel Oil and Kerosene Sales, 2007," December 2008, DOE/EIA-0535(07).

for ULSD thereafter. The phase-in path for ULSD is available in the input file lfblending.xlsx (and listed in Table F-8 below).

Table F-8. Distillate consumption distribution

		2006	2007	2008	2009	2010	2011	2012	2013
DSU	HWY	0.443	0.76	0.76	0.76	0.9	1	1	1
DSL	HWY	0.557	0.24	0.24	0.24	0.1	0	0	0
N2H	HWY	0	0	0	0	0	0	0	0
DSU	ONR	0	0	0	0	0.443	1	1	1
DSL	ONR	0	0.443	1	1	0.557	0	0	0
N2H	ONR	1	0.557	0	0	0	0	0	0
DSU	OLM	0	0	0	0	0	0	0.443	1
DSL	OLM	0	0.443	1	1	1	1	0.557	0
N2H	OLM	1	0.557	0	0	0	0	0	0

HWY = on-highway, ONR = off-highway (non-road), OLM = off-highway, locomotive, marine
DSU = ultra-low sulfur diesel, DSL = low-sulfur diesel, N2H = heating oil
Source: U.S. Energy Information Administration, Office of Energy Analysis

Heating oil is not subject to ULSD rules; however, many states in the northeast and mid-Atlantic have passed mandates requiring ultra-low sulfur heating oil by a certain date (Table F-9).

Table F-9. States and start years for ultra-low sulfur heating oil

State	Census division	Start year
Connecticut	CD 1	2018
Maine	CD 1	2018
Massachusetts	CD 1	2018
New Hampshire	CD 1	2018
Rhode Island	CD 1	2018
Vermont	CD 1	2018
New Jersey	CD 2	2016
New York	CD 2	2012
Pennysylvania	CD 2	2020
Delaware	CD 5	2016
District of Columbia	CD 5	2018

Source: “SULFUR & BIOHEAT REQUIREMENTS FOR No. 2 HEATING OIL IN THE NORTHEAST & MID-ATLANTIC STATES”, Chart 1. Summary, updated 6-29-2017, https://oilandenergyonline.com/files/6515/5992/8794/NEMARegion_HOspecs_2017.pdf

Estimation of regional conversion coefficients

Differing regional definitions necessitate the conversions of certain variables from one regional structure to another. Regional conversions are not extensive in the LFMM, but they are needed for some refinery input prices, refinery fuel consumption, and cogeneration information. The factors are used to convert prices, consumption, or cogeneration from the regional level used by the LFMM to census divisions. We generate these factors based on state-level ADU capacity, each mapped and aggregated into LFMM regions, and then mapped into census divisions, as a percentage of capacity in each LFMM region.

Other data, such as corn feedstock to ethanol plants, are mapped from 16 coal demand regions to the 8 domestic LFMM regions by determining the states that overlap the two regional representations.

Product pipeline capacities and tariffs

Products in the LFMM are produced domestically, imported, or exported based on domestic demand levels and relative market economics. Within the LFMM, products are transported between refining (LFMM) regions mainly by pipeline, but they can move by more expensive modes (such as rail, truck, tanker, or barge), usually if pipeline flows exceed available capacity.

Originally, we based the pipeline distribution network in the LFMM on the distribution network used by its predecessor model PMM (last used for AEO2012). We later updated the network for AEO2014 based on a proposal from OnLocation Inc, and we generated corresponding capacity and tariff data from online news releases, pipeline company sites, and detailed research of FERC filings. Only a few minor updates were made for AEO2018, but we made major changes in AEO2019 and AEO2020. Current data used for the current AEO are listed in Tables F-10. Note that these data represent an aggregate of multiple product pipelines connecting the regions.

Table F-10. Product pipeline capacity and tariff data in the Liquid Fuels Market Module represented in the current *Annual Energy Outlook*

RefReg code	Source region	RefReg code	Destination region	Capacity (1,000 barrels per day)	Tariff range (2024 dollars per barrel)
1	PADD I	3	PADD II, lakes	240	$1.55 – $2.60
2	PADD II, inland	3	PADD II, lakes	2,492	$1.60 – $2.00
3	PADD II, lakes	1	PADD I	250	$2.15 – $3.60
4	PADD III, gulf	3	PADD II, lakes	330	$1.60 – $2.65
4	PADD III, gulf	5	PADD III, inland	4,434	$0.90 – $1.50
5	PADD III, inland	1	PADD I	3,000	$1.75 – $2.95
5	PADD III, inland	2	PADD II, inland	2,450	$1.40 – $2.30
5	PADD III, inland	6	PADD IV	84.7	$1.35 – $2.30
5	PADD III, inland	8	PADD V, other	200	$1.90 – $1.95
6	PADD IV	2	PADD II, inland	40	$1.80 – $2.25
6	PADD IV	8	PADD V, other	66	$2.10 – $3.50
7	PADD V, California	8	PADD V, other	128	$1.20 – $2.00

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

Cogeneration methodology

Electricity consumption in the refinery is a function of the throughput of each unit. Sources of electricity consist of refinery power generation, utility purchases, and refinery cogeneration. We model power generators and cogenerators in the LFMM as separate units that are allowed to compete along with purchased electricity.

Refinery cogeneration

The refinery cogeneration unit in the LFMM was modeled using historical data as a guideline. We aggregate cogeneration activity for each refinery to the LFMM regional level. We estimated cogeneration capacity from the 2024 version of Form EIA-923, *Power Plant Operations Report*. We derived cogeneration operating costs from the 1980 Office of Technology Assessment (OTA) report *Industrial Cogeneration*. We also derived cogeneration capacity (including planned capacity) for each LFMM region from Form EIA-923. The LP limits utilization to 90% of capacity. No unplanned builds for refinery cogeneration are allowed.

The LFMM can model cogeneration of electricity and steam at the petroleum refinery by burning still gas and natural gas (assumed to be 33% and 67%, respectively). In general, refinery cogeneration units tend to be small, designed to supply the refinery's steam and electricity needs and to sell a small amount of leftover capacity to the grid. However, if it is profitable to sell cogeneration electricity, the LP constraints will reflect the assumption that all of it is sold. Likewise, if it is not profitable, the model will reflect the assumption that none of it is sold.

Non-petroleum feedstock supplies

Cellulosic biomass

The LFMM models cellulosic ethanol (pyrolysis) production processes. The feedstock consists of three cellulosic biomass supply curves (agricultural residue, forest residue, and urban wood waste) that are generated from data provided by the Renewable Fuels Module (RFM) of NEMS.

Corn

The LFMM also models ethanol production from corn. Price/quantity (P/Q) corn-to-ethanol data from the RFM (NEMS) is used to develop the corn feedstock supply curve for the domestic LFMM regions. We use the initial P/Q pair to represent step five on the 29-step iso-elastic supply curve. Thus, the first five steps represent the starting production level projected by RFM, and the remaining steps represent the additional supply available (not to exceed a maximum of 10 times the initial production level (step 5) if the LFMM determines it economical to demand more. The RFM data are translated into LFMM corn supply curves by:

1. Defining corn supply and price by coal demand regions from total corn supply curves provided by Polysys (in RFM):
    a. Regional corn supply-for-ethanol = total U.S. corn supply-for-ethanol * ratio of regional total corn supply to U.S. total corn supply [use step 3 from all supply curves]
    b. National (U.S.) corn supply prices = step 3 from national (U.S.) total corn supply curves

   c. For years 2030 and beyond, set regional corn supply prices = prices in 2029 * growth rate set as a function of the change in world oil price (WOP)

2. Defining corn supply and price by LFMM regions from coal demand region price/supply information and LFMM region adjustments:
   a. Use mapping shares (CoalDReg2RefRegMap) to redistribute regional corn supply-for-ethanol from coal demand regions to LFMM regions. A small adjustment factor applies (CornTranSupMove)
   b. Apply cost differential data to the national (U.S.) corn supply price to set prices by LFMM regions

These initial P/Q pair (Po and Qo) are set as step 5 on a 29-step supply curve, and a maximum quantity on the curve is set to 10 times the initial Qo. The regional curves are set as iso-elastic supply curves, using regional elasticities, as described below.

$$P_s/P_o = (Q_s/Q_o)^{elas}$$

$$P_s = P_o * (Q_s/Q_o)^{elas}$$

where

P_s = price of corn on step s, 2008 dollars per bushel;

Q_s = quantity of corn supply on step s, 1,000 bushels per day;

Po, Qo = initial price and quantity of corn supply provided by RFM, 2008 dollars per bushel, 1,000 bushels per day; and

elas = price elasticity for each LFMM region; 0.50 for LFMM regions 2 and 3 (Midwestern region) and 0.75 for all other LFMM regions.

Seed oils, fats, and greases

The production of biodiesel and renewable diesel from virgin vegetable oil, yellow grease, and white grease are represented in the LFMM. Virgin oil supplies to biodiesel and renewable diesel producers consist of regional quantities of soybean, cottonseed, canola, and sunflower oils. Yellow grease consists primarily of used cooking oil from restaurants. As such, it is available nationwide and is assumed to grow at the same rate that population grows. White grease consists of fats from rendering. We assume total fat production is 5.51 gallons per person per year, of which 1.84 gallons per person per year is available for production. As of AEO2020, yellow grease and white grease production are combined into a single, iso-elastic supply curve in the LFMM, and we assume initial regional supply (Qo) to be 67% of total regional fat production available for biodiesel and renewable diesel. We assume the initial regional price (Po) for the grease supply curve is 67% of the soybean oil price, defined further below. The regional supply curves are then generated using the same iso-elastic algorithm defined for generating the corn supply curve but using a 0.50 supply elasticity for all regions.

The approach to defining biodiesel feedstock supply data representing virgin oil supply (soybean and seed oils) in the LFMM was updated for AEO2021. The soybean oil available for production is determined from soybean supply, soy oil production, and cost data from Polysys (in the RFM). The soybean oil production data are reallocated from coal demand regions into LFMM regions, and we assume the quantity available for biodiesel and renewable diesel production is 34.3%. We estimate the other seed oil production from other data sources. The total of these two production levels define the initial quantity (Qo) of virgin oil (FCO) supplies for biodiesel production for each LFMM region. We estimate the corresponding price (Po) to be the average U.S. price for soybean oil provided by Polysys. The regional FCO supply curves are generated using the same iso-elastic algorithm defined for generating the corn supply curve but using a 1.2 supply elasticity for all regions.

E85 infrastructure representation and availability curve

The large renewable fuel volumes mandated by EISA2007 (and modified by EPA each year) can be met by a number of biofuels options represented in LFMM, including ethanol fuel use in vehicles. By existing rules and regulations, ethanol can only enter the transportation fuel supply as E10, E15, or E85. Once the E10 market is saturated, any ethanol used to meet the mandate would have to come into the market as E15 or E85. The E85 market requires the building of additional station infrastructure, which in turn is used to build an E85 availability curve. We use this curve in the LFMM to project E85 availability, and corresponding gasoline and E85 prices. These prices are then passed to the Transportation Demand Module (TDM) in NEMS.

Prior to AEO2021, E85 infrastructure costs for modifying the retailer equipment to dispense E85 fuel were estimated and amortized over the lifetime of the equipment. Demand for E85 is represented by a logit function describing the interaction between E85 availability (in other words, the percentage of retail stations that provide E85 within a given region), the price differential between motor gasoline and E85, and the share of flex-fuel vehicle demand that is E85 rather than E10 or E15. This interaction is still an option in the LFMM.

Beginning with AEO2021, we added a second optional (more simplistic) approach to establish the E85 availability curve used in LFMM. It assumes a starting E85 to gasoline price ratio, E85 availability and estimated growth, and price elasticities. As with the original approach, a step-wise linear supply curve is created with each step representing a price differential for E85 and a corresponding E85 availability and demand (determined using the logit function mentioned above) for the LFMM to incorporate as a decision variable.

Renewable Fuels Standard (EISA 2007) representation

The LFMM includes provisions, outlined in Section 202 of the Energy Independence and Security Act of 2007 (EISA2007) concerning the Renewable Fuels Standard (RFS), which require increases in the total U.S. consumption of renewable fuels. The total renewable fuels requirement is expanded over the requirement specified in the Energy Policy Act of 2005 to include four nested categories of renewable fuels: total, advanced biofuels, cellulosic biofuels, and biomass-based diesel (biodiesel and renewable diesel). Advanced biofuels are defined to be any renewable fuel, other than ethanol derived from corn starch, that has lifecycle greenhouse gas emissions that are at least 50% less than baseline lifecycle greenhouse gas emissions (gasoline or diesel fuel, EISA2007 Sec 201(1)(C)). Cellulosic biofuel is renewable fuel derived from any cellulose, hemicellulose, or lignin that is derived from renewable biomass and that has lifecycle greenhouse gas emissions that are at least 60% less than the baseline lifecycle greenhouse gas emissions. Biomass-based diesel is defined as a renewable fuel that is biodiesel as defined in Section 312(f) of the Energy Policy Act of 1992 (42 U.S.C. 13220(f)) and that has lifecycle greenhouse gas emissions that are at least 50% less than the baseline lifecycle greenhouse gas emissions. This category was expanded to include renewable diesel. Cellulosic biofuels and biomass-derived diesel both count toward the advanced biofuels subtotal. The EPA is authorized to reduce mandate levels per specific authority in the statute. The original RFS target volumes are as follows:

Table F-11. Energy Independence and Security Act of 2007 Renewable Fuels Standard schedule

billion ethanol-equivalent gallons per year

Year	Renewable fuels	Advanced biofuels	Cellulosic biofuels	Biomass-based diesel
2006	4	0	0	0
2007	4.7	0	0	0
2008	9	0	0	0
2009	11.1	0.6	0	0.75
2010	12.95	0.95	0.1	0.975
2011	13.95	1.35	0.25	1.2
2012	15.2	2	0.5	1.5
2013	16.55	2.75	1	1.92
2014	18.15	3.75	1.75	1.92
2015	20.5	5.5	3	1.92
2016	22.25	7.25	4.25	1.92
2017	24	9	5.5	1.92
2018	26	11	7	1.92
2019	28	13	8.5	1.92
2020	30	15	10.5	1.92
2021	33	18	13.5	1.92
2022	36	21	16	1.92

Source: Energy Independence and Security Act of 2007, https://www.govinfo.gov/content/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf.

Since calendar year 2005, we have been required to project the use of all transportation fuel, biomass-based diesel, and cellulosic biofuel for the following calendar year no later than October 31 (Clean Air Act 42 U.S.C 7545(o)(3)(A)). The existing waiver authority is retained, but specific procedures are established for waivers of the cellulosic biofuels requirement and for the biomass-based diesel requirement. By November 30 of each calendar year, the EPA Administrator is required to adjust the cellulosic biofuels requirement for up to one year using EIA's projected quantity as a guideline if the projected available quantity is lower than the requirement. The legislation also directs the EPA

Administrator to make credits for cellulosic biofuels available at a price equal to $3.00 per gallon (wholesale gasoline price) or $0.25 per gallon, whichever is greater. The number of cellulosic biofuels credits is limited "…to the minimum applicable volume (as reduced under this subparagraph) of cellulosic biofuel for that year." (EISA2007 Section 202(e)(2)(D)(i))

The EPA Administrator must reduce the applicable volumes in succeeding years after issuing wavers that pass a certain size threshold, stated as follows. If either 20% or more of any requirement is waived in two consecutive years, or if 50% or more of any requirement is waived in one year, then the applicable volume requirement must be modified in all years following the final year of the waiver. However, applicable volumes for years before 2016 may not be modified under this subparagraph (EISA2007 Section 202(e)(3)(F)). The LFMM LP implicitly accounts for this EPA authority by including escape valve variables in the relevant LP constraints.

EISA2007 also allows the EPA Administrator to waive the biomass-based diesel requirement if the market circumstances are determined to cause the price of biomass-based diesel to increase substantially. The waiver is limited to 15% of the annual requirement for a maximum of 60 days but can be renewed thereafter every 60 days. No credits are required in the event of a waiver of the biomass-based diesel requirement. The EPA Administrator may also reduce the applicable volume of renewable fuel and advanced biofuels requirements by the same or a lesser volume (EISA2007 Section 202(e)(3)(E)(ii)).

The first RFS rule (known as RFS1) was modified by a second rule in 2009 and amendments in 2010 (known as RFS2). EPA issued annual volume requirements each year when it became apparent that the biofuel industry was unable to produce and import sufficient advanced biofuels to hit the mandated targets. In 2023, EPA issued a Set rule to provide annual volume obligations for three years 2023-25. In 2025, EPA proposed Set2 to cover two years 2026-27.The annual volume requirements for 2010 through 2025 as issued by EPA in each final rule are summarized in the table on https://www.epa.gov/renewable-fuel-standard/renewable-fuel-annual-standards.

For AEO2025, the LFMM used RFS targets based on the June 2023 EPA final rulemaking. These targets include adjustments to remove components that are not modeled in the LFMM (such as biogas).

Table F-12. Renewable Fuels Standard schedule implemented in AEO2025

billion ethanol-equivalent gallons per year

Year	Renewable fuels	Advanced biofuels	Cellulosic biofuels	Biomass-based diesel
2006	4	0	0	0
2007	4.7	0	0	0
2008	9	0	0	0
2009	11.1	0.6	0	0.75
2010	12.95	0.95	0	0.975
2011	13.95	1.35	0	1.2
2012	15.03	2.00	0	1.5
2013	15.56	2.75	0.001	1.92
2014	15.85	2.64	0.001	2.445
2015	16.64	2.76	0.002	2.595
2016	16.98	3.25	0.023	2.73
2017	17.28	3.58	0.013	2.72
2018	17.90	3.70	0.020	2.92
2019	18.50	4.23	0.020	2.94
2020	17.13	4.63	0	3.645
2021	18.31	4.52	0.029	3.645
2022	20.28	5.03	0.032	4.14
2023	20.39	5.14	0.043	4.23
2024	20.51	5.51	0.055	4.57
2025	21.02	6.02	0.07	5.03
2026	21.02	6.02	0.07	5.03
2027	21.02	6.02	0.07	5.03
2028	21.02	6.02	0.07	5.03
2029	21.02	6.02	0.07	5.03
2030	21.02	6.02	0.07	5.03

California Low Carbon Fuel Standard (LCFS) , Oregon Clean Fuels Program (CFP), and Washington Clean Fuel Standard (WACFS) representation

The Low Carbon Fuel Standard (LCFS), which is administered by the California Air Resources Board (CARB),[20] was signed into law on January 12, 2010, and was followed by several amendments over the years. The regulated parties under this legislation are generally the fuel producers or importers who sell motor gasoline or diesel fuel in California. This legislation is designed to reduce the carbon intensity (CI) of motor gasoline and diesel fuels sold in California by 20% from 2010 through 2030 through the increased sale of alternative *low-carbon* fuels. Each alternative low carbon fuel has its own CI based on a life cycle analyses conducted under the guidance of CARB for a number of approved fuel pathways. The

[20] LCFS Final Regulation Order. http://www.arb.ca.gov/regact/2009/lcfs09/finalfro.pdf.

CIs are calculated on an energy equivalent basis and measured in grams of CO_2 equivalent emissions per megajoule (gCO_2e/MJ).

For the Oregon and Washington programs, the mathematical representation is the same. They both have different targets/timelines for motor gasoline and diesel fuel sold in the respective state and are both intended to reduce the CI of the fuels sold in-state. See the tables below. The Oregon program is administered by OR's Department of Environmental Quality, while the Washington program is administered by WA's Department of Ecology.

The current AEO Reference case uses the CARB mandated CIs and approved fuel pathways included in the LCFS.[21] The Reference case also includes the latest targets from Oregon and Washington's standards. To represent non-compliance, we computed a monetary penalty to encourage compliance within the Reference case based on relevant provisions in the California Health and Safety Code.[22]

The CIs are a measure of the complete well-to-wheels (or lifecycle) emissions of each fuel pathway and include indirect land use change (ILUC) penalties for applicable fuels. The ILUC penalty is an additional CI value that attempts to account for potential land use changes as a result of increased biofuels production. The science behind the ILUC penalty is relatively new, so we expect potential revisions and updates to these numbers as the LCFS evolves. These fuel pathways include existing technologies such as Midwestern corn ethanol, imported sugarcane ethanol, and soy-based biodiesel, as well as a number of *next-generation* technologies such as cellulosic ethanol and biomass-to-liquid diesel fuels. The legislation also has provisions that allow non-regulated parties such as electricity and hydrogen producers to contribute to the carbon reduction.

The following tables show carbon intensity targets and factors used for the current AEO. The LFMM converts these data from g CO_2e/MJ into 1,000 metric ton C/trillion Btu using the conversion factor (cf) 3.475332 (for example, g CO_2e/MJ / cf = 1,000 metric ton C/trillion Btu).

[21] LCFS Fuel Pathway Lookup Tables. https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.
[22] California Health and Safety Code, Section 43025 through 43029.

Table F-13. California Low Carbon Fuel Standard carbon intensity targets

	Carbon intensity (grams of CO_2 equivalent emissions per megajoule)	
Year	Diesel	Motor gasoline
2011	94.41	95.55
2012	94.18	95.31
2013	96.99	97.90
2014	96.50	97.41
2015	95.52	96.42
2016	94.54	95.43
2017	93.07	93.94
2018	91.60	92.46
2019	94.17	93.23
2020	92.92	91.98
2021	91.66	90.74
2022	90.41	89.50
2023	89.15	88.25
2024	87.89	87.01
2025	86.64	85.77
2026	85.38	84.52
2027	84.13	83.28
2028	82.87	82.04
2029	81.62	80.80
2030−2050	80.36	79.55

Source: California Air Resources Board, Low Carbon Fuel Standard

Table F-14. Oregon Clean Fuels Program carbon intensity targets

	Carbon intensity (grams of CO_2 equivalent emissions per megajoule)	
Year	Diesel	Motor gasoline
2016	99.39	98.37
2017	99.14	98.13
2018	98.61	97.66
2019	98.12	97.16
2020	97.12	96.18
2021	96.12	95.19
2022	94.63	93.71
2023	93.14	92.23
2024	91.64	90.75
2025	89.65	88.78
2026-2050	89.65	88.75

Source: Oregon Clean Fuels Program

Table F-15. Washington Clean Fuel Standard carbon intensity targets

	Carbon intensity (grams of CO_2 equivalent emissions per megajoule)	
Year	**Diesel**	**Motor gasoline**
2023	98.44	99.61
2024	97.97	99.11
2025	96.95	98.11
2026	95.96	97.11
2027	94.97	96.11
2028	93.49	94.6
2029	92	93.1
2030	90.52	91.6
2031	89.04	90.1
2032	89.04	90.1
2033	89.04	90.10
2034	79.14	80.09
2035	79.14	80.09
2036	79.14	80.09
2037	79.14	80.09
2038-2050	79.14	80.09

Source: Washington State Legislature, Carbon Intensity Standards Tables 1 & 2.

Table F-16. Sample carbon intensities

Fuel	Description and notes	Grams of CO_2 equivalent emissions per megajoule	Note
DSU	Petroleum diesel (ULSD)	100.45	(1)
FAME_SBO	Biodiesel: soybean (Midwest soybean oil transesterification)	54.79	(2)
FAME_PLM	Biodiesel: palm oil	83.25	(3)
FAME_YGR	Biodiesel: waste yellow grease	20.43	(4)
FAME_WGR	Biodiesel: white grease (calculated)	35.01	(5)
NERD_SBO	Renewable diesel: Midwest soybean oil hydrogenation	44.01	(6)
NERD_PLM	Renewable diesel: palm oil (calculated)	82.16	(7)
NERD_YGR	Renewable diesel: yellow grease (calculated)	6.049	(8)
NERD_WGR	Renewable diesel: tallow (white grease)	34.31	(9)
MG	California E10 baseline gasoline	100.82	(10)
ETA	Ethanol (advanced): Brazilian sugarcane	46.82	(11)
ETC	Ethanol: cellulosic (average)	28.61	(12)
ETH	Ethanol: California average corn (80% dry mill, 20% wet mill)	70.06	(13)
GN_SBO	Green naphtha: same as NERD	39.75	(14)
GN_PLM	Green naphtha: same as NERD (calculated)	44.01	(15)
GN_YGR	Green naphtha: same as NERD	39.75	(16)
GN_WGR	Green naphtha: same as NERD	39.75	(16)

Fuel	Description and notes	Grams of CO_2 equivalent emissions per megajoule	Note
CNG	Natural gas (nonrenewable) (for CNG vehicles)	79.21	(17)
EV	Electricity (average California mix)	23.97	(18)
LPG	LPG from refinery	83.19	(19)
PYO	Distillate refined from pyrolysis oil	27.33	(20)
PYO	Naphtha refined from pyrolysis oil	23.63	(21)

(1) Search for *Diesel* under “Fuel Type” and *Lookup Table* under “Class” within “current-pathways_al.xlsx” file accessed through “Current Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm .

(2) Look on California’s Air Resource Board website https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm .

(3) Same as soy biodiesel because palm oil feedstock is lumped with other seed oil feedstock within the LFMM. Note that neither CARB nor the EPA considers palm-oil-based biodiesel to be a fuel worth considering in any significant supply. See EPA's discussion of palm oil biodiesel on pp. 60−63 in the "Draft Regulatory Impact Analysis: Changes to Renewable Fuel Standard Program," published May 2009.

(4) Search for *Biodiesel* under “Fuel Category” and *UCO* under “Feedstock” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(5) Search for *Biodiesel* under “Fuel Category” and *Tallow and/or Fat* under “Feedstock” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(6) August 2019 memo from Sean Hill (DOE/EIA/OEA/PNGBA).

(7) Assumed value of Midwest Soy Renewable Diesel value in lieu of ARB value.

(8) Search for *Renewable diesel* under “Fuel Category” and *Used Cooking Oil* under “Feedstock” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(9) Search for *Renewable diesel* under “Fuel Category” and *Tallow* under “Feedstock” within “current-pathways_all.xlsx” file accessed through “Current Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(10) Search for *CARBOB* under “Fuel Type” and *Lookup Table* under “Class” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm .

(11) Search for *Ethanol* under “Fuel Category” and *Sugarcane* under “Feedstock” and *Brazil* under “Facility Location” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(12) Search for *Ethanol-Cellulosic* under “Fuel Category” within “current-pathways_all.xlsx” file accessed through “Current Fuel Pathways” link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(13) Substitute pathways table for 2019 on California’s Air Resource Board website https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/subpathwaytable.htm.

(14) Search for *Renewable Naphtha* under "Fuel Type" and *Tier 2* under "Class" within "current-pathways_all.xlsx" file accessed through "Current Fuel Pathways" link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(15) Assumed same values as same feedstock Renewable Diesel pathways.

(16) Assumed same values as same feedstock Renewable Naphtha SBO pathway.

(17) Search for *Compressed Natural Gas* under "Fuel Type" and *Lookup Table* under "Class" within "current-pathways_all.xlsx" file accessed through "Current Fuel Pathways" link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(18) Takes into account EER for better electric car use of energy over conventional vehicle. Table ES-8 of "Proposed Regulation to Implement the Low Carbon Fuel Standard vol. 1" from CARB (Table ES-8 of http://www.arb.ca.gov/fuels/lcfs/030409lcfs_isor_vol1.pdf).

(19) Search for *LPG* under "Fuel Type" and *Lookup Table* under "Class" within "current-pathways_all.xlsx" file accessed through "Current Fuel Pathways" link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

(20) Search for *Renewable Diesel* under "Fuel Type" and *from Forest REsidue* under "Feedstock" within "current-pathways_all.xlsx" file accessed through "Current Fuel Pathways" link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

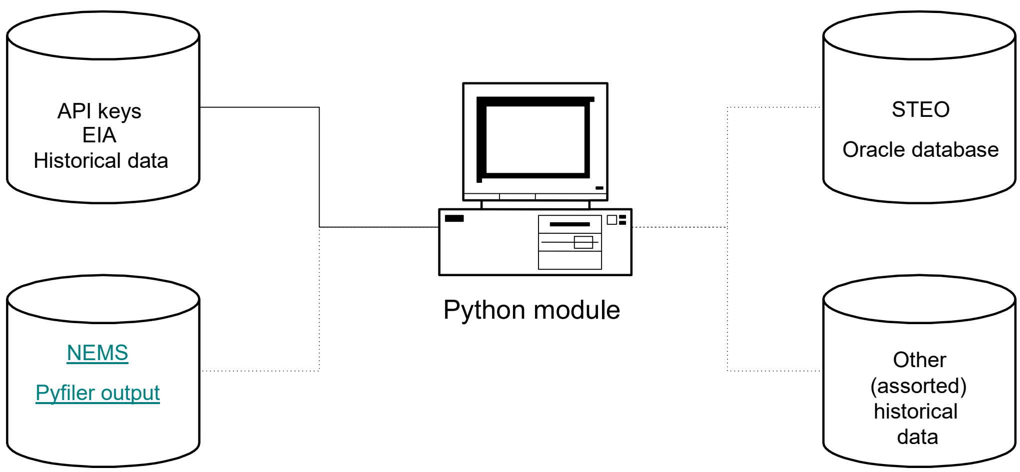
(21) Search for *Renewable Gasoline* under "Fuel Type" and *from Forest Residue* under "Feedstock" within "current-pathways_all.xlsx" file accessed through "Current Fuel Pathways" link at https://ww3.arb.ca.gov/fuels/lcfs/fuelpathways/pathwaytable.htm.

Appendix G. Historical Data Processing

Processing data for LFMM history file

The LFMM uses historical data from a variety of sources. A series of Python modules and scripts collects and aggregates these data to prepare the LFMM input file rfhist.txt. It primarily collects from the Oil and Gas Information Resource System (OGIRS), by way of Application Programming Interface (API) keys, which contains most historical wholesale price and volume information. It also primarily collects from the *Short-Term Energy Outlook* (STEO) Oracle database, which contains data from the STEO forecast that begins at the end of the historical period to the first NEMS projection year. We add a few additional individual historical data elements as inputs or exogenous calculations to the Python module, as well as historical NEMS results from Pyfiler output, as described below.

Figure 4. Database linkages for historical data processing



Accessing data

The following provides some background on the component databases that are used in processing the historical input file.

- API Keys: The Python module collects most of its historical data through the use of API keys, which allow access to historical EIA survey data. The Python module includes two tables, one for annual data and one for monthly data. The tables list API source keys, which are used to query and pull the historical dataset from the API Open Database each time the Python module is run and updated.

Table G-1. API source key list sample

LFMM variable	Definition	API keys
RFQEXCRD	Crude oil exports in thousands of barrels per day	PET.MCREXUS2.M
RFQICRD	Crude oil imports in millions of barrels per day	PET.MCRIMUS2.M
RFBDSTCAP	Base distillation capacity in millions of barrels per calendar day	PET.MOCLEUS2.M
RFDSTUTL	Distillation rate as a percentage	PET.MOPUEUS2.M
RFQEXPRDT	Product exports in millions of barrels per day	PET.MBCEXUS2.M

Most of data used by the LFMM are pulled from the API as annual numbers. The only time monthly data are used is for the computation of refinery operable capacity or for year-to-date current year data for refinery input/output variables that aren't provided by the STEO. For refinery operable capacity, the January data values are the previous year's capacity.

The EIA historical survey database is mostly complete; however, the database has a few missing fields. To prevent errors when the queries are executed, the short list of missing values has zeroes appended to them in the Python script that creates the rfhist.txt file.

- STEO Oracle database: The current month's STEO output database is created using a series of Excel spreadsheets generated from the STEO Oracle database. The Python module performs STEO benchmarking which uses STEO output files to read in the STEO values used for the current STEO years and use as inputs to the LFMM. The STEO benchmarking process ensures AEO projections align with STEO model results.
- NEMS Pyfiler Data: Additional historical data is pulled from previous NEMS runs to populate historical data that is either no longer available in EIA API source keys or comes from historical NEMS/LFMM model results. The data are from the NEMS program Pyfiler, which pulls NEMS run data from existing AEO restart files.

Additional sources are used to create the LFMM history data file.

- Refinery fuel consumption data in Table 10a of the *Refinery Capacity Report*.
- Global Database Variables: The user defines the AEO year manually in the Python module code. The STEO_year variable does not need to be updated manually because it is automated from STEO release information.
- Historical E85 Prices: Historical E85 Retail Prices are manually updated using the *Clean Cities Alternative Fuel Price Report* provided by DOE's Office of Energy Efficiency and Renewable Energy.

Data processing queries

After all the data from the different sources have been input (or linked) to the Python module, several queries are executed to manipulate the data into LFMM variables. The numbers correspond with the position of the variable being generated in the rfhist.txt file. This code should not need to be changed if the definition of the LFMM variable it represents is not changed. If the definition changes, the individual variable query can be examined and edited.

LFMM variables are linked to variables in input databases (primarily API and STEO) in the Python module by matching up sector and fuel type. A complete list of mappings for both historical and STEO years is available in the following table. Multiple entries for an LFMM variable indicate that more than one API or STEO variable is needed to calculate the value for these variables. The multiple entries are summed to obtain the LFMM variable.

Table G-2. LFMM variables linked to input databases

LFMM variable	Definition	API keys or data source	STEO years
RFQEXCRD	Crude oil exports in thousands of barrels per day (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCREXUS2.M	Assume last historical year
RFQICRD	Crude oil imports in millions of barrels per day (MMb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCRIMUS2.M	CONXPUS use last historical year percentage to parse to PADDs
RFBDSTCAP	Base distillation capacity (MMb/cd)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MOCLEUS2.M	Not available; use most recent historical year proxy: CODIPUS
RFDSTUTL	Distillation utilization rate as a percentage	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MOPUEUS2.M	CODIPUS/last historical year's capacity
RFQEXPRDT	Product exports (MMb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MBCEXUS2.M http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MTPEXUS2.M http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MNGEXUS2.M http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MUOEXUS2.M http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOOR_EEX_NUS-Z00_MBBLD.M http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOOXXFE_EEX_NUS-Z00_MBBLD.M	Last year's exports of petroleum products
RFPQIPRDT	Product imports (MMb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MNGIMUS2.M	PANIPUS
		http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MTPIMUS2.M	Last year's exports of petroleum products
CRDUNACC	Unaccounted crude oil		COUNPUS
CRDSTWDR	Crude oil stock withdrawals	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCRSCUS2.M	COSQ_DRAW COSX_DRAW
RFQPRCG	Refinery and blender processing gain	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MPGRPUS1.M	PAGLPUS
BLDIMP	Blending component imports	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MBCIMUS2.M	MBNIPUS

LFMM variable	Definition	API keys or data source	STEO years
RFHCXH2IN	Hydrogen input to refineries	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOOOH_YIR_NUS_MBBLD.M	
RFQNGPF	Natural gas used as feedstock for hydrogen production (thousand cubic feet)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.8_NA_8NGFSHY_NUS_MMCF.M	
OTHPRDSP	Other liquids product supplied	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MOLUPUS2.M	
PRDSTKWDR	Product stocks withdrawals	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MTTSCUS2.M	Assume zero
OTHETHCD	Ethanol produced from other feedstock		
RFETHE85	Ethanol for E85 production		Assume zero
RFMTBI	Imported MTBE	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MMTIMUS2.M	Assume zero
RFETHIN	Total ethanol into refinery (MMb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MFERO_NUS_1.M	
RFPQUFC	Total imports of unfinished crude oil	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MUOIMUS2.M	UORIPUS
RFSPRFR	Rf spr fill rate	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCSSCUS1.M	CONQPUS
AST	Asphalt product supplied (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MAPUPUS2.M	ARTCPUS
COK	Petroleum coke product supplied (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCKUPUS2.M	PCTCPUS
JTA	Jet fuel kerosene product supplied (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MKJUPUS2.M	JFTCPUS
BIODIMP	U.S. imports of biodiesel supplied (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOORXFE_IM0_NUS-Z00_MBBLD.M	BDNIPUS
BIODEXP	U.S. exports of biodiesel (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOORDB_EEX_NUS-Z00_MBBLD.M	BDNIPUS
RENEWDIMP	U.S. imports of renewable diesel (Mb/d)	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPOORDO_IM0_NUS-Z00_MBBLD.M	

LFMM variable	Definition	API keys or data source	STEO years
TDIESEL	Product supplied; distillate fuel oil, 0 ppm−15 ppm sulfur	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MD0UP_NUS_2.M	
N2H	Product supplied; no. 2 distillate	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MGAUPUS2.M	DFTCPUS
KER	Product supplied; kerosene	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MKEUPUS2.M	KSTCPUS
LPG	Product supplied; LPG	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MLPUPUS2.M	LGTCPUS
N6B	U.S. ending stocks of residual fuel oil, less than 0.31% sulfur, annual	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPPRH_VPP_NUS_MBBLD.M	RFTCPUS * High%
N6I	U.S. ending stocks of residual fuel oil, greater than 1% sulfur, annual	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.M_EPPRX_VPP_NUS_MBBLD.M	RFTCPUS* Low%
OTH	Product supplied, other petroleum	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MGAUPUS2.M	AVTCPUS
		http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MLUUPUS2.M	LUTCPUS
		http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MNSUPUS2.M	SNTCPUS
PCF	Product supplied, petrochemical feeds	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MPCUP_NUS_2.M	
STG	Product supplied, still gas	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MSGUPUS2.M	SGTCPUS
RFQPRDT	Total product supplied	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MTTUPUS2.M	Sum STEO product quantities
		http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MCRUPUS2.M	
TRG	Product supplied; motor gasoline	http://api.eia.gov/series/?api_key=YOUR_API_KEY_HERE&series_id=PET.MGFUPUS2.M	MGTCPUS
QELETH	Historical electricity use at ethanol plants	Multiply EOFPPUS ethanol production by Tony Radich's formulas for energy consumption	
QCLETH	Historical coal use at ethanol plants	OGIRS - m_epooxe_eex_nus	
PETHM (87$bbl)	Historical ethanol price		

LFMM variable	Definition	API keys or data source	STEO years
ETHEXP	Historical ethanol exports		
QCLRF	Refinery fuel—coal	Paste in from Table 47 of PSA	Assume last historical year ratio of fuel to production Average refiner price of residual fuel oil
QDSRF	Refinery fuel—distillate fuel oil	Paste in from Table 47 of PSA	
QELRF	Refinery fuel—purchased electricity	Paste in from Table 47 of PSA	
QLGRF	Refinery fuel—LPG	Paste in from Table 47 of PSA	
QNGRF	Refinery fuel—natural gas	Paste in from Table 47 of PSA	
QOTRF	Refinery fuel—other	Paste in from Table 47 of PSA	
QPCRF	Refinery fuel—petroleum coke	Paste in from Table 47 of PSA	
QRSRF	Refinery fuel—residual fuel	Paste in from Table 47 of PSA	
QSGRF	Refinery fuel—still gas	Paste in from Table 47 of PSA	
PASIN	Asphalt, road oil, industrial		RFTCUUS
PDSCM	Distillate, commercial		DSTCUUS
PDSEL	Distillate, electricity (plus petroleum coke)		Product prices in 1987 dollars per million British thermal units
PDSIN	Distillate, industrial	SEDS	DSTCUUS
PDSRS	Distillate, residential	SEDS	DSTCUUS
PDSTR	Distillate, transportation	SEDS	DSTCUUS
PJFTR	Jet fuel, transportation	SEDS	JKTCUUS
PKSCM	Kerosene, commercial	SEDS	JKTCUUS
PKSIN	Kerosene, industrial	SEDS	JKTCUUS
PKSRS	Kerosene, residential	SEDS	JKTCUUS

LFMM variable	Definition	API keys or data source	STEO years
RFQEXCRD	Crude oil exports in thousands of barrels per day	OGIRS - MCREXPx2 (Where x is PADD#)	Assume last historical year
PLGCM	Liquid petroleum gases, commercial		PRTCUUS
PLGIN	Liquid petroleum gases, industrial		PRTCUUS
PLGRS	Liquid petroleum gases, residential		PRTCUUS
PLGTR	Liquid petroleum gases, transportation		PRTCUUS
PMGCM	Motor gasoline, commercial		MGEIRUS
PMGIN	Motor gasoline, industrial		MGEIRUS
PMGTR	Motor gasoline, transportation		MGEIRUS
PPFIN	Petrochemical feedstocks, industrial		PRTCUUS
PRHEL	Residual fuel, high-sulfur, electricity		RFTCUUS
PRHTR	Residual fuel, high-sulfur, transportation		RFTCUUS
PRLCM	Residual fuel, low-sulfur, commercial		RFTCUUS
PRLEL	Residual fuel, low-sulfur, electricity		RFTCUUS
PRLIN	Residual fuel, low-sulfur, industrial		RFTCUUS
PETTR	E85 price	EERE: *Alternative Fuel Report*	
OG GEN GRID90	Cogeneration in thousands of British thermal units (MBtu)	Form EIA-923 Survey	Use last historical year for STEO years 1 and 2
PT GEN GRID90	Cogeneration in millions of British thermal units (MMBtu)	Form EIA-923 Survey	
NG GEN GRID90	Cogeneration in MMBtu	Form EIA-923 Survey	
OT GEN GRID90	Cogeneration in MMBtu	Form EIA-923 Survey	

OG GEN OWN 90	Cogeneration in MMBtu	Form EIA-923 Survey
PT GEN OWN 90	Cogeneration in MMBtu	Form EIA-923 Survey
NG GEN OWN 90	Cogeneration in MMBtu	Form EIA-923 Survey
OT GEN OWN 90	Cogeneration in MMBtu	Form EIA-923 Survey
OG CAP	Capacity in megawatts (MW)	Form EIA-923 Survey
PT CAP	Capacity MW	Form EIA-923 Survey
NG CAP	Capacity MW	Form EIA-923 Survey
OT CAP	Capacity MW	Form EIA-923 Survey
OG FUL	Cogeneration fuel consumption	Form EIA-923 Survey
PT FUL	Cogeneration fuel consumption	Form EIA-923 Survey
NG FUL	Cogeneration fuel consumption	Form EIA-923 Survey
OT FUL	Cogeneration fuel consumption	Form EIA-923 Survey

Creating LFMM flat-file

To create the final rfhist.txt, we first aggregate file query results and organize them into Python dataframe tables before exporting them to Excel output spreadsheets. The three output tables are **GAMS_US_RFHIST**, **Product_price_data**, and **Refinery_fuel_consumption**.

The final step once the output Excel spreadsheets are saved is to run the Python script that generates the final rfhist.txt file. We convert the three spreadsheets into the necessary rfhist.txt file using the create_RFHIST.py script, which is run using a Python integrated development environment. The create_RFHIST.py Python script also manipulates some data from within the script, so any data or values not found in the Excel spreadsheets may be updated from within create_RFHIST.py.

Processing other historical data

In addition to developing an input history file, the LFMM uses other historical data to develop some inputs and to support analysis of the model results. This section describes these data updates, which are usually done on an annual basis.

Historical prices and margins

Historical wholesale and end-use prices from Form EIA-782 are aggregated and presented in a table by product type and census division. The end-use transportation prices include state and federal taxes, but for jet fuel and LPG state taxes are not included before 1995. Following the discontinuation of Form EIA-782 in 2022, wholesale prices are assumed using historical wholesale and retail prices. Retail price data remains available.

Differentials with the world oil price (the refiner acquisition cost of imported oil from Form EIA-14) are also calculated by product type and census division and presented in a table for analyzing similar margin calculations from the LFMM. The margins include the 1% local tax that is currently being added to gasoline price projections.

Appendix H. NEMS Restart File Variables in LFMM

Table H-1. NEMS Restart Variables in LFMM

Restart Variable	Unit	Dimension Name	Description	Input or Output
AB32_AB_ALLOW_P	$1987/ton	Year	Allowance price, 87$/tonne-C	Input
AB32_AB_COVD_EM_REF	MMton CO2	Year	Covered emissions - refining	Output
CCATSDATA_CST_ETH_INV	$/ton	Census Regions, Years	Investment cost for carbon capture from ethanol production	Output
CCATSDATA_CST_ETH_OM	$/ton	Census Regions, Years	O&M cost for carbon capture from ethanol production	Output
CCATSDATA_SUP_ETH_45Q	$/ton	Census Regions, Years	CO2 volumes from ethanol production that are 45Q eligible	Output
CCATSDATA_SUP_ETH_NTC	$/ton	Census Regions, Years	CO2 volumes from ethanol production, no tax credit	Output
COALEMM_PLNT_EMF	Scalar	ECP Plant Types, Coal Ranks	EMF by Plant Type and Coal Rank	Output
COALEMM_RCLCLNR	Percent	Coal Demand Region, Year, Utility Demand Sectors	% Removal of SO2 by ECP Coal Plant	Output
COGEN_CGREFCAP	MW	Census Regions, Years, Num of Combined Heat and Power Fuels	Combined heat and power fuel consumption - refinery	Output
COGEN_CGREFGEN	GWh	Census Regions, Years, Num of Combined Heat and Power Fuels	Combined heat and power generation - refinery	Output
COGEN_CGREFQ	tBtu	Census Regions, Years, Num of Combined Heat and Power Fuels	Combined heat and power fuel capacity - refinery	Output
CONVFACT_API50PL	API		API 50+ crude oil	Output
CONVFACT_APICA	API		California crude oil	Output
CONVFACT_APICAMG	API		California motor gasoline	Output
CONVFACT_APICRDDOM	API		API domestic crude oil production	Output
CONVFACT_APICRDEXP	API		API crude oil exports	Output
CONVFACT_APICRDIMP	API		API crude oil imports	Output
CONVFACT_APIDIL	API		Dilbit	Output
CONVFACT_APIHVSO	API		Heavy sour crude oil	Output
CONVFACT_APIHVSW	API		Heavy sweet crude oil	Output
CONVFACT_APILLSW	API		Light light sweet crude oil	Output
CONVFACT_APILTSO	API		Light sour crude oil	Output
CONVFACT_APILTSW	API		Light sweet crude oil	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
CONVFACT_APIMDSO	API		Medium sour crude oil	Output
CONVFACT_APIMMSO	API		Medium medium sour crude oil	Output
CONVFACT_APISYN	API		Syncrude	Output
CONVFACT_CFASQ	Btu/b		Asphalt and Road Oil	Input
CONVFACT_CFAVQ	Btu/b		Aviation Gasoline	Input
CONVFACT_CFBIOBUTE	Btu/b	Year	Biobutanol	Input
CONVFACT_CFBIOD	Btu/b	Year	Biodiesel	Input
CONVFACT_CFBTLLIQ	Btu/b	Year	Liquids from biomass	Output
CONVFACT_CFBUQ	Btu/b		Butane	Input
CONVFACT_CFCBOB	Btu/b	Year	Conventional motor gasoline before oxygenate blend	Input
CONVFACT_CFCBQ	Btu/b	Year	Ca Air Resource Board BOB	Input
CONVFACT_CFCBTLLIQ	Btu/b		Liquids from coal-biomass combo (1=coal 2=biomass 3=total)	Output
CONVFACT_CFCCQ	Btu/b	Year	Catalytic petroleum coke	Input
CONVFACT_CFCRDCA	Btu/b	Year	California crude oil	Output
CONVFACT_CFCRDDIlbIT	Btu/b	Year	Dilbit	Output
CONVFACT_CFCRDHVSOUR	Btu/b	Year	Heavy sour crude oil	Output
CONVFACT_CFCRDHVSWT	Btu/b	Year	Heavy sweet crude oil	Output
CONVFACT_CFCRDLSCOND	Btu/b	Year	Lease condensate	Output
CONVFACT_CFCRDLT2SWT	Btu/b	Year	Light light sweet crude oil	Output
CONVFACT_CFCRDLTSOUR	Btu/b	Year	Light sour crude oil	Output
CONVFACT_CFCRDLTSWT	Btu/b	Year	Light sweet crude oil	Output
CONVFACT_CFCRDMD2SOUR	Btu/b	Year	Medium medium sour crude oil	Output
CONVFACT_CFCRDMDSOUR	Btu/b	Year	Medium sour crude oil	Output
CONVFACT_CFCRDSYN	Btu/b	Year	Syncrude	Output
CONVFACT_CFCTLLIQ	Btu/b	Year	Liquids from coal	Output
CONVFACT_CFDSCM	Btu/b	Year	Commercial distillate	Output
CONVFACT_CFDSCQ	Btu/b	Year	Ca Air Resource Board diesel	Output
CONVFACT_CFDSEL	Btu/b	Year	Electric power distillate	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
CONVFACT_CFDSIN	Btu/b	Year	Industrial distillate (diesel) includes ulsd	Output
CONVFACT_CFDSLQ	Btu/b	Year	Low sulfur diesel	Output
CONVFACT_CFDSQ	Btu/b		Distillate	Output
CONVFACT_CFDSQT	Btu/b	Year	Total distillate	Output
CONVFACT_CFDSRS	Btu/b	Year	Residential distillate	Output
CONVFACT_CFDSTR	Btu/b	Year	Transportation distillate (diesel) includes ulsd	Output
CONVFACT_CFDSUQ	Btu/b	Year	Ultra low sulfur diesel	Input
CONVFACT_CFE85Q	Btu/b	Year	E85	Output
CONVFACT_CFEEQ	Btu/b		Ethane	Input
CONVFACT_CFELQ	Btu/kWh		Electricity	Input
CONVFACT_CFETQ	Btu/b	Year	Ethanol	Input
CONVFACT_CFFTLIQ	Btu/b		Fischer-Tropsch liquid streams	Input
CONVFACT_CFIBQ	Btu/b		Isobutane	Input
CONVFACT_CFIMUO	Btu/b	Year	Unfinished oil imports - weighted average	Input
CONVFACT_CFJFK	Btu/b		Jet Fuel - Kerosene	Input
CONVFACT_CFJFQ	Btu/b	Year	Jet Fuel	Output
CONVFACT_CFLGQ	Btu/b	Year	Liquefied Petroleum Gas	Output
CONVFACT_CFLUQ	Btu/b		Lubricants	Output
CONVFACT_CFMEQT	Btu/b		Methanol	Input
CONVFACT_CFMGQ	Btu/b	Year	Motor Gasoline	Output
CONVFACT_CFNGL	Btu/b	Year	Natural Gas Liquids	Output
CONVFACT_CFNPQ	Btu/b		Naphthas, special or otherwise	Input
CONVFACT_CFOTQ	Btu/b	Year	Other Petroleum	Input
CONVFACT_CFPCQ	Btu/b		Petroleum Coke	Input
CONVFACT_CFPET	Btu/b		Pure (undenatured) ethanol	Input
CONVFACT_CFPFQ	Btu/b	Year	Petrochemical Feedstocks	Output
CONVFACT_CFPPQ	Btu/b		Pentanes Plus	Input
CONVFACT_CFPRQ	Btu/b		Propane	Input
CONVFACT_CFRBOB	Btu/b	Year	Reformulated motor gasoline before oxygenate blend	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
CONVFACT_CFRGQ	Btu/b	Year	Motor Gasoline (Reformulated)	Output
CONVFACT_CFRSQ	Btu/b		Residual Fuel	Input
CONVFACT_CFSGQ	Btu/b		Still Gas	Input
CONVFACT_CFTGQ	Btu/b	Year	Motor Gasoline (no Oxygenates)	Output
CONVFACT_CFUBAQ	Btu/b	Year	Pyrolysis oils	Input
CORNTO_	Dimension		Uses for corn	Input
CRSTEP_	Dimension		Crude oil curve steps	Input
CYCLEINFO_CURIRUN	Dimension		Current run cycle number	Input
ECPCAP_	Dimension		ECP Plant Types	Input
ECPFPH_	Dimension		Years in Full ECP Plannin	Input
EMABLK_JBUIN	$1987/Btu	Year	Butane	Input
EMABLK_JBUINPF	$1987/Btu	Year	Butane feedstocks	Input
EMABLK_JCLCLNR	$1987/Btu	Years, Utility Demand Sectors	Tax/allowance price adder	Input
EMABLK_JDSCM	$1987/Btu	Year	Distillate	Input
EMABLK_JDSEL	$1987/Btu	Year	Distillate	Input
EMABLK_JDSIN	$1987/Btu	Year	Distillate	Input
EMABLK_JDSRS	$1987/Btu	Year	Distillate	Input
EMABLK_JDSTR	$1987/Btu	Year	Distillate	Input
EMABLK_JETTR	$1987/Btu	Year	Ethanol	Input
EMABLK_JISIN	$1987/Btu	Year	Isobutane	Input
EMABLK_JISINPF	$1987/Btu	Year	Isobutane feedstocks	Input
EMABLK_JJFTR	$1987/Btu	Year	Jet Fuel	Input
EMABLK_JKSCM	$1987/Btu	Year	Kerosene	Input
EMABLK_JKSIN	$1987/Btu	Year	Kerosene	Input
EMABLK_JKSRS	$1987/Btu	Year	Kerosene	Input
EMABLK_JLUIN	$1987/Btu	Year	Lubricants	Input
EMABLK_JMGCM	$1987/Btu	Year	Motor Gasoline	Input
EMABLK_JMGIN	$1987/Btu	Year	Motor Gasoline	Input
EMABLK_JMGTR	$1987/Btu	Year	Motor Gasoline	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
EMABLK_JOTIN	$1987/Btu	Year	Tax/allowance price adder	Input
EMABLK_JOTTR	$1987/Btu	Year	Other Petroleum	Input
EMABLK_JPCIN	$1987/Btu	Year	Tax/allowance price adder	Input
EMABLK_JPFIN	$1987/Btu	Year	Tax/allowance price adder	Input
EMABLK_JPPIN	$1987/Btu	Year	Pentanes plus	Input
EMABLK_JPPINPF	$1987/Btu	Year	Pentanes plus feedstocks	Input
EMABLK_JRHEL	$1987/Btu	Year	Residual Fuel, High Sulfur	Input
EMABLK_JRHTR	$1987/Btu	Year	Residual Fuel, High Sulfur	Input
EMABLK_JRLCM	$1987/Btu	Year	Residual Fuel, Low Sulfur	Input
EMABLK_JRLEL	$1987/Btu	Year	Residual Fuel, Low Sulfur	Input
EMABLK_JRLIN	$1987/Btu	Year	Residual Fuel, Low Sulfur	Input
EMABLK_JRLTR	$1987/Btu	Year	Residual Fuel, Low Sulfur	Input
EMEBLK_EDSTR	MMton/quad	Year	Distillate - Transportation	Input
EMEBLK_EJFTR	MMton/quad	Year	Jet Fuel - Transportation	Input
EMEBLK_ELGTR	MMton/quad	Year	Liquid Petroleum Gases - Transportation	Input
EMEBLK_EMGTR	MMton/quad	Year	Motor Gasoline - Transportation	Input
EMEBLK_ENGIN	MMton/quad	Year	Natural Gas - Industrial	Input
EMEBLK_EOTIN	MMton/quad	Year	Other petroleum - Industrial	Input
EMEBLK_EOTTR	MMton/quad	Year	Other Petroleum - Transportation	Input
EMEBLK_ERSTR	MMton/quad	Year	Residual Fuel - Transportation	Input
EMISSION_CCS_PMM	MMton CO2		Carbon capture and storage from LFMM	Output
EMISSION_EMEL_PHG	$/ton	Coal Demand Region, Year	Mercury Penalty Price by Group and Year	Input
EMISSION_EMELPSO2	$/ton	Years, SO2 Compliance Groups	CDS Sulfur dioxide emission allowance price	Input
EMISSION_EMETAX	$1987/ton		Excise (Consumption) Tax by Fuel	Input
EMISSION_EMTRC	Mmton	Census Regions, Air Emissions Particulates, Years	Trans Emissions by Region	Input
EMISSION_EXTRARISK	Percent	Year	Extra risk premium above and beyond	Input
EMISSION_NUM_SO2_GRP	Dimension		Number of SO2 Compliance Groups	Input
EMISSION_SO2_SHR_BY_CLRG	Fraction	Coal Demand Region, SO2 Compliance Groups	Fraction of SO2 Emissions by Compliance Group by C	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
HMMBLK_PH2RF	$1987/b	Census Regions, Years	Price of H2 to refineries by census division	Input
INDOUT_INQLGHP	tBtu	Census Regions, Years	Consumption of LPG for heat and power (excludes re	Input
INDREP_QCCRF	tBtu		Refinery cat coke consumption	Output
INSTEP_	Dimension		Product import curve step	Input
INTOUT_BRENT_PRICE	$1987/b	Year	Brent spot price	Output
INTOUT_ICOCANADA	MMb/d	Year	Imports from Canada - crude oil	Input
INTOUT_ICOMEXICO	MMb/d	Year	Imports from Mexico - crude oil	Input
INTOUT_ICONORTHSEA	MMb/d	Year	Imports from North Sea - crude oil	Input
INTOUT_ICOOPAMERICAS	MMb/d	Year	Imports from OPEC South and Central America - crud	Input
INTOUT_ICOOPEC	MMb/d	Year	Imports from OPEC - crude oil	Input
INTOUT_ICOOPNOAFRICA	MMb/d	Year	Imports from OPEC North Africa - crude oil	Input
INTOUT_ICOOPPERSIANGULF	MMb/d	Year	Imports from OPEC Persian Gulf - crude oil	Input
INTOUT_ICOOPWESTAFRICA	MMb/d	Year	Imports from OPEC West Africa - crude oil	Input
INTOUT_ICOOTHERAFRICA	MMb/d	Year	Imports from other Africa - crude oil	Input
INTOUT_ICOOTHERAMERICAS	MMb/d	Year	Imports from other South and Central America - cru	Input
INTOUT_ICOOTHERASIA	MMb/d	Year	Imports from other Asia - crude oil	Input
INTOUT_ICOOTHERMIDEAST	MMb/d	Year	Imports from Other Middle East - crude oil	Input
INTOUT_ICOTOTAL	MMb/d	Year	Total imports - crude oil	Input
INTOUT_IHPASIA	MMb/d	Year	Imports from Asia - heavy oil	Input
INTOUT_IHPCANADA	MMb/d	Year	Imports from Canada - heavy oil	Input
INTOUT_IHPCARIBBEAN	MMb/d	Year	Imports from Caribbean - heavy oil	Input
INTOUT_IHPNORTHEUROPE	MMb/d	Year	Imports from North Europe - heavy oil	Input
INTOUT_IHPOPAMERICAS	MMb/d	Year	Imports from OPEC South and Central America - heav	Input
INTOUT_IHPOPEC	MMb/d	Year	Imports from total OPEC - heavy oil	Input
INTOUT_IHPOPNOAFRICA	MMb/d	Year	Imports from OPEC North Africa - heavy oil	Input
INTOUT_IHPOPPERSIANGULF	MMb/d	Year	Imports from OPEC Persian Gulf - heavy oil	Input
INTOUT_IHPOPWESTAFRICA	MMb/d	Year	Imports from OPEC West Africa - heavy oil	Input
INTOUT_IHPOTHER	MMb/d	Year	Imports from Other - heavy oil	Input
INTOUT_IHPSOUTHEUROPE	MMb/d	Year	Imports from South Europe - heavy oil	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
INTOUT_IHPTOTAL	MMb/d	Year	Total imports - heavy oil	Input
INTOUT_ILPASIA	MMb/d	Year	Imports from Asia - light oil	Input
INTOUT_ILPCANADA	MMb/d	Year	Imports from Canada - light oil	Input
INTOUT_ILPCARIBBEAN	MMb/d	Year	Imports from Caribbean - light oil	Input
INTOUT_ILPNORTHEUROPE	MMb/d	Year	Imports from North Europe - light oil	Input
INTOUT_ILPOPAMERICAS	MMb/d	Year	Imports from OPEC South and Central America - ligh	Input
INTOUT_ILPOPEC	MMb/d	Year	Imports from total OPEC - light oil	Input
INTOUT_ILPOPNOAFRICA	MMb/d	Year	Imports from OPEC North Africa - light oil	Input
INTOUT_ILPOPPERSIANGULF	MMb/d	Year	Imports from OPEC Persian Gulf - light oil	Input
INTOUT_ILPOPWESTAFRICA	MMb/d	Year	Imports from OPEC West Africa - light oil	Input
INTOUT_ILPOTHER	MMb/d	Year	Imports from Other - light oil	Input
INTOUT_ILPSOUTHEUROPE	MMb/d	Year	Imports from South Europe - light oil	Input
INTOUT_ILPTOTAL	MMb/d	Year	Total imports - light oil	Input
INTOUT_IT_WOP	$1987/b	Year	World oil prices	Output
INTOUT_P_C_MC_DEMAND	$1987/b	Refine Reg 9 Demand Curve, Years, Petroleum Prod Streams	Price steps for Caribbean & Maritime Canada demand	Input
INTOUT_P_FOREIGN_CRUDE	$1987/b	Crude Type	Price steps for international crude supply	Input
INTOUT_P_NON_US_DEMAND	$1987/b	Crude Type	Price steps for non-US crude demand	Input
INTOUT_P_TOTAL_CRUDE	$1987/b	Crude Oil Curve Steps, Years	Price steps for world crude like liquids supply	Input
INTOUT_Product_Export_P	$1987/b	Petroleum Prod Streams, International Regions, Prod Import Curve Steps, Years	Product export demand curve prices	Input
INTOUT_Product_Export_Q	MMb/d	Petroleum Prod Streams, International Regions, Prod Import Curve Steps, Years	Product export demand curve quantities	Input
INTOUT_Product_Import_P	$1987/b	Petroleum Prod Streams, International Regions, Prod Import Curve Steps, Years	Product import supply curve prices	Input
INTOUT_Product_Import_Q	MMb/d	Petroleum Prod Streams, International Regions, Prod Import Curve Steps, Years	Product import supply curve quantities	Input
INTOUT_Q_C_MC_DEMAND	MMb/d	Refine Reg 9 Demand Curve, Years, Petroleum Prod Streams	Quantity steps for Caribbean & Maritime Canada dem	Input
INTOUT_Q_FOREIGN_CRUDE	MMb/d	Crude Type	Quantity steps for international crude supply	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
INTOUT_Q_NON_US_DEMAND	MMb/d	Crude Type	Quantity steps for non-US crude demand	Input
INTOUT_Q_TOTAL_CRUDE	MMb/d	Crude Oil Curve Steps, Years	Quantity steps for world crude like liquids supply	Input
INTOUT_START_PRICE	$1987/b	Year	World oil price as specified in memo	Input
INTOUT_WTI_PRICE	$1987/b	Year	West Texas Intermediate spot price	Input
INTREG _	Dimension		International regions	Input
LCFS_C_	Dimension		Number of LCFS Categories	Output
LFMMOUT_AB32_DS	$1987/Btu	Year	Distillate AB32 tax adder from LP	Output
LFMMOUT_AB32_ET	$1987/Btu	Year	E85 AB32 tax adder from LP	Output
LFMMOUT_AB32_JF	$1987/Btu	Year	Jet fuel AB32 tax adder from LP	Output
LFMMOUT_AB32_KS	$1987/Btu	Year	Kerosene AB32 tax adder from LP	Output
LFMMOUT_AB32_MG	$1987/Btu	Year	Motor gas AB32 tax adder from LP	Output
LFMMOUT_AB32_PR	$1987/Btu	Year	Propane AB32 tax adder from LP	Output
LFMMOUT_AB32JETCOVER	Scalar	Year	Portion of CA jet fuel covered under AB32	Output
LFMMOUT_BIMQTY	Mb/d		Biodiesel production by type and PADD	Output
LFMMOUT_BIOBUTEEXP	Mb/d	Year	Exports of biobutanol	Output
LFMMOUT_BIOBUTEIMP	Mb/d	Year	Imports of biobutanol	Output
LFMMOUT_BIOBUTEPRICE	$1987/b	Year	Biobutanol price	Output
LFMMOUT_BIOBUTESTK	Mb/d	Year	Biobutanol stock withdrawal (+) or addition (-)	Output
LFMMOUT_BIODEXPPD	Mb/d	PADD Region, Years	Biodiesel exports by PADD	Other
LFMMOUT_BIODIMPPD	Mb/d	PADD Region, Years	Biodiesel imports by PADD	Output
LFMMOUT_BIODSTKCHG	Mb/d	Year	Biodiesel stock withdrawal (+) or addition (-)	Output
LFMMOUT_CFP_Actual	MMton CO2 per Trill	LCFS Categories, Years	CFP Actual - Achieved Values	Output
LFMMOUT_CFP_Baseline	MMton CO2 per Trill	LCFS Categories, Years	CFP Baseline Values	Output
LFMMOUT_CFP_Carb_Offset	MMton CO2	LCFS Categories, Years	CFP Carbon Offset	Output
LFMMOUT_CFP_Offset_Prc	$1987/Mton CO2	LCFS Categories, Years	CFP Offset Price	Output
LFMMOUT_CFP_PeToTrills	MMton	LCFS Categories, Years	CFP Temp Variables Total Btus of Petroleum Fuels	Output
LFMMOUT_CFP_Waiver	MMton CO2	LCFS Categories, Years	CFP Waivers Purchased	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
LFMMOUT_CORNCD	MMBu	Uses for Corn, Census Regions, Years	Corn Consumed in Production of Ethanol	Output
LFMMOUT_DIST_FUEL	Mb/d		Distillate breakout	Other
LFMMOUT_DOM_CONSUME	Dimension		Domestic consumption section	Output
LFMMOUT_ETHSTKCHG	Mb/d	Year	Ethanol stock withdrawal (+) or addition (-)	Output
LFMMOUT_ETHTOT	Mb/d	PADD Region, Years	Total ethanol production by PADD	Output
LFMMOUT_FEEDSTOCKS	Dimension		Feedstock section	Output
LFMMOUT_GRAINCD	MMBu	Census Regions, Years	Grain (non-corn) used to make ethanol	Output
LFMMOUT_GRD2DSQTY	Mb/d	PADD Region, Years	Renewable diesel to distillate by PADD level	Output
LFMMOUT_GRN2MGQTY	Mb/d	PADD Region, Years	Renewable diesel to gasoline by PADD level	Output
LFMMOUT_GROSS_EXPORT	Dimension		Gross export section	Output
LFMMOUT_GROSS_IMPORT	Dimension		Gross import section	Output
LFMMOUT_INTERMEDIATE	Dimension		Intermediate stream section	Output
LFMMOUT_LCFS_Actual	MMton CO2 per Trill	LCFS Categories, Years	LCFS Actual - Achieved Values	Output
LFMMOUT_LCFS_Baseline	MMton CO2 per Trill	LCFS Categories, Years	LCFS Baseline Values	Output
LFMMOUT_LCFS_Carb_Offset	MMton CO2	LCFS Categories, Years	LCFS Carbon Offset	Output
LFMMOUT_LCFS_Offset_Prc	$1987/Mton CO2	LCFS Categories, Years	LCFS Offset Price	Output
LFMMOUT_LCFS_PeToTrills	MMton	LCFS Categories, Years	LCFS Temp Variables Total Btus of Petroleum Fuels	Output
LFMMOUT_LCFS_Waiver	MMton CO2	LCFS Categories, Years	LCFS Waivers Purchased	Output
LFMMOUT_LFDENCONS	Mb/d		Denaturant details	Other
LFMMOUT_LFDENPROD	Mb/d		Denaturant details	Other
LFMMOUT_LFEXPLEASE			Switch to allow exports of lease condensate	Output
LFMMOUT_LFMMCODE			Return code from LFMM	Output
LFMMOUT_LFREFRENT			Switch to activate crude oil export logic to simul	Output
LFMMOUT_MOTOR_FUEL	Mb/d		Motor gasoline breakout	Output
LFMMOUT_P_CRUDE_EXPORTS	$1987/b		Crude Export Prices to World Model	Output
LFMMOUT_P_CRUDE_IMPORTS	$1987/b		Imported crude oil price	Output
LFMMOUT_P_CRUDE_TO_CAN	$1987/b	PADD Region, Crude Type, Years	Price of crude oil exported to Canada	Other

Restart Variable	Unit	Dimension Name	Description	Input or Output
LFMMOUT_P_RFCRUDEINP	$1987/b	PADD Region, Crude Type, Years	Crude oil refinery price by refinery region and type	Output
LFMMOUT_PROFIT_BBL	$1987/b	PADD Region, Years	Refinery Marginal Profit	Output
LFMMOUT_Q_CRUDE_EXPORTS	Mb/d		Crude Export Quantities to World Model	Output
LFMMOUT_Q_CRUDE_IMPORTA	Mb/d		Actual Crude Imports from LFMM	Output
LFMMOUT_Q_CRUDE_IMPORTS	Mb/d		Target Crude Imports to World Model	Output
LFMMOUT_Q_CRUDE_TO_CAN	Mb/d	PADD Region, Crude Type, Years	Amount of crude oil exported to Canada	Output
LFMMOUT_QBIOBUTE	Mb/d	Census Regions, Years	Consumption of biobutanol by Census division	Output
LFMMOUT_QNGRFPD	tBtu	PADD Region, Years	Natural gas for GTL	Output
LFMMOUT_REF_CAP	Mb/d		Refinery Capacity	Output
LFMMOUT_REF_UTL	Fraction		Refinery Utilization	Output
LFMMOUT_REFGAIN	Mb/d	PADD Region	Refinery Gain by Refinery Region and Refinery Type	Output
LFMMOUT_REFINE_PROD	Dimension		Refined products section	Output
LFMMOUT_REFINPBU	Mb/d	PADD Region, Years	Refinery inputs of butane	Other
LFMMOUT_REFINPET	Mb/d	PADD Region, Years	Refinery inputs of ethane	Other
LFMMOUT_REFINPIS	Mb/d	PADD Region, Years	Refinery inputs of isobutane	Other
LFMMOUT_REFINPOO	Mb/d	PADD Region, Years	Refinery inputs of other olefins	Other
LFMMOUT_REFINPPP	Mb/d	PADD Region, Years	Refinery inputs of natural gasoline	Other
LFMMOUT_REFINPPR	Mb/d	PADD Region, Years	Refinery inputs of propane	Other
LFMMOUT_REFINPPY	Mb/d	PADD Region, Years	Refinery inputs of propylene	Other
LFMMOUT_REFPRODBU	Mb/d	PADD Region, Years	Refinery production of butane	Other
LFMMOUT_REFPRODET	Mb/d	PADD Region, Years	Refinery production of ethane	Other
LFMMOUT_REFPRODIS	Mb/d	PADD Region, Years	Refinery production of isobutane	Other
LFMMOUT_REFPRODOO	Mb/d	PADD Region, Years	Refinery production of other olefins	Other
LFMMOUT_REFPRODPP	Mb/d	PADD Region, Years	Refinery production of natural gasoline	Other
LFMMOUT_REFPRODPR	Mb/d	PADD Region, Years	Refinery production of propane	Other
LFMMOUT_REFPRODPY	Mb/d	PADD Region, Years	Refinery production of propylene	Other
LFMMOUT_RENEWDIMP	Mb/d	Census Regions, Years	Renewable diesel imports by census	Output
LFMMOUT_RENEWDIMPPD	Mb/d	PADD Region, Years	Renewable diesel imports by PADD	Output
LFMMOUT_RFBIOBUTECD	Mb/d	Census Regions, Years	Production of biobutanol by Census division	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
LFMMOUT_RFBIOBUTERR	Mb/d	PADD Region, Years	Production of biobutanol by refinery region	Output
LFMMOUT_RFCRUDEINP	Mb/d	PADD Region, Crude Type, Years	Crude oil refinery inputs by refinery region and type	Output
LFMMOUT_RFCRUDEWHP	$1987/b	PADD Region, Crude Type, Years	Crude oil wellhead price by refinery region and type	Output
LFMMOUT_RFIPQAG	Mb/d	PADD Region, Years	IMPORTS Aviation Gasoline (P.Q)	Output
LFMMOUT_RFIPQAR3	Mb/d	PADD Region, Years	IMPORTS atmospheric residuum (P.Q)	Output
LFMMOUT_RFIPQAS	Mb/d	PADD Region, Years	IMPORTS Asphalt (P.Q)	Output
LFMMOUT_RFIPQBU	Mb/d	PADD Region, Years	IMPORTS butane (P.Q)	Output
LFMMOUT_RFIPQCBOB	Mb/d	PADD Region, Years	IMPORTS CBOB (P.Q)	Output
LFMMOUT_RFIPQCD	Mb/d	PADD Region, Years	IMPORTS Carb diesel (P.Q)	Output
LFMMOUT_RFIPQCG	Mb/d	PADD Region, Years	IMPORTS CarBOB (P.Q)	Output
LFMMOUT_RFIPQDL	Mb/d	PADD Region, Years	IMPORTS LOW SULFUR DIESEL (P.Q)	Output
LFMMOUT_RFIPQDS	Mb/d	PADD Region, Years	IMPORTS DISTILLATE FUEL OIL (P.Q)	Output
LFMMOUT_RFIPQDU	Mb/d	PADD Region, Years	IMPORTS ULTRA LOW SULFUR DIESEL (P.Q)	Output
LFMMOUT_RFIPQET	Mb/d	PADD Region, Years	IMPORTS ethane (P.Q)	Output
LFMMOUT_RFIPQGO3	Mb/d	PADD Region, Years	IMPORTS gas oil (P.Q)	Output
LFMMOUT_RFIPQIS	Mb/d	PADD Region, Years	IMPORTS isobutane (P.Q)	Output
LFMMOUT_RFIPQJF	Mb/d	PADD Region, Years	IMPORTS JET FUEL (P.Q)	Output
LFMMOUT_RFIPQLU	Mb/d	PADD Region, Years	IMPORTS Lubricants (P.Q)	Output
LFMMOUT_RFIPQMG	Mb/d	PADD Region, Years	IMPORTS CONV MOTOR GASOLINE (P.Q)	Output
LFMMOUT_RFIPQMN3	Mb/d	PADD Region, Years	IMPORTS medium naphtha (P.Q)	Output
LFMMOUT_RFIPQPC	Mb/d	PADD Region, Years	IMPORTS petroleum coke (P.Q)	Output
LFMMOUT_RFIPQPF	Mb/d	PADD Region, Years	IMPORTS PETROCHEMICAL FEEDSTOCKS (P.Q)	Output
LFMMOUT_RFIPQPP	Mb/d	PADD Region, Years	IMPORTS pentanes plus (P.Q)	Output
LFMMOUT_RFIPQPR	Mb/d	PADD Region, Years	IMPORTS propane (P.Q)	Output
LFMMOUT_RFIPQPY	Mb/d	PADD Region, Years	IMPORTS propylene (P.Q)	Output
LFMMOUT_RFIPQRBOB	Mb/d	PADD Region, Years	IMPORTS RBOB (P.Q)	Output
LFMMOUT_RFIPQRG	Mb/d	PADD Region, Years	IMPORTS REFORMULATED MOTOR GASOLINE (P.Q)	Output
LFMMOUT_RFIPQRH	Mb/d	PADD Region, Years	IMPORTS HIGH SULFUR RESIDUAL FUEL (P.Q)	Output
LFMMOUT_RFIPQRL	Mb/d	PADD Region, Years	IMPORTS LOW SULFUR RESIDUAL FUEL (P.Q)	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
LFMMOUT_RFOTHERINP	Mb/d	PADD Region, Years	Other refinery inputs by refinery region and type	Output
LFMMOUT_RFPRDDIESEL	Mb/d	Census Regions, Years	Diesel refinery production	Output
LFMMOUT_RFS_WAIVER	$1987/b		RFS waiver price by constraint category	Output
LFMMOUT_RFSACTUAL	Mb/d		Actual RFS production levels from prior year Period 2	Output
LFMMOUT_RFSCREDITS	Bgal		RFS credits by category and biofuel	Output
LFMMOUT_RFSCREDPRC	$1987/b		RFS credit price by constraint category	Output
LFMMOUT_RFSDSRS	$1987/b	Census Regions, Years	RFS contribution to heating oil price	Output
LFMMOUT_RFSDSTR	$1987/b	Census Regions, Years	RFS contribution to diesel price	Output
LFMMOUT_RFSJFTR	$1987/b	Census Regions, Years	RFS contribution to jet fuel price	Output
LFMMOUT_RFSMANDATES	Bgal		RFS mandates by category and biofuel	Output
LFMMOUT_RFSMGTR	$1987/b	Census Regions, Years	RFS contribution to motor gasoline price	Output
LFMMOUT_RFSRBOB	$1987/b	Census Regions, Years	RFS contribution to RBOB price	Output
LFMMOUT_RFSREVMANDATE	Bgal		Revised RFS mandates by category	Other
LFMMOUT_RFSSAFETY	Bgal		RFS safety valve usage in	Output
LFMMOUT_SAF2JTQTY	Mb/d	PADD Region, Years	HEFA-SPK renewable jet to jet by PADD level	Output
LFMMOUT_SBOQGD	Mb/d	PADD Region, Years	Green nap or dist from seed oil	Output
LFMMOUT_SBOQRJH	Mb/d	PADD Region, Years	HEFA-SPK renewable jet from seed oil	Output
LFMMOUT_WGRQGD	Mb/d	PADD Region, Years	Green nap or dist from white grease	Output
LFMMOUT_WGRQRDH	Mb/d	PADD Region, Years	green diesel (RDH) from white grease	Output
LFMMOUT_WGRQRJH	Mb/d	PADD Region, Years	HEFA-SPK renewable jet from white grease	Output
LFMMOUT_YGRQGD	Mb/d	PADD Region, Years	Green nap or dist from yellow grease	Output
MACOUT_MC_JPGDP		Years 1987-1989	Chained price index-gross domestic product	Input
MACOUT_MC_NP	MM	Census Regions, Years	Total population, including armed forces overseas	Input
MACOUT_MC_RMCORPBAA	Percent	Year	Rate on industrial BAA bonds	Input
MACOUT_MC_RMTCM10Y	Percent	Year	10 year Treasury note yield	Input
MAXNF2_	Dimension		Maximum Number of EMM Fue	Input
MAXNFR_	Dimension		Maximum Number of EMM Fue	Input
MCDETAIL_MC_DETAIL			Contains stuff for peripheral FTAB table	Input
MCSTEP_	Dimension		Refine reg 9 demand curve	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
MNCRUD_	Dimension		Crude oil types (LFMM)	Input
MPBLK_PASIN	$1987/MMBtu	Census Regions, Years	Asphalt- Road Oil- Industrial	Output
MPBLK_PDSAS	$1987/Btu	Census Regions, Years	Distillate - All Sectors	Output
MPBLK_PDSCM	$1987/Btu	Census Regions, Years	Distillate - Commercial	Output
MPBLK_PDSEL	$1987/Btu	Census Regions, Years	Distillate - Electricity	Output
MPBLK_PDSIN	$1987/Btu	Census Regions, Years	Distillate - Industrial	Output
MPBLK_PDSRS	$1987/Btu	Census Regions, Years	Distillate - Residential	Output
MPBLK_PDSTR	$1987/Btu	Census Regions, Years	Distillate - Transportation	Output
MPBLK_PELIN	$1987/Btu	Census Regions, Years	Purchased Electricity - Industrial	Input
MPBLK_PETTR	$1987/Btu	Census Regions, Years	Ethanol - Transportation	Output
MPBLK_PGIIN	$1987/Btu	Census Regions, Years	Natural Gas, Noncore - Industrial	Input
MPBLK_PJFTR	$1987/MMBtu	Census Regions, Years	Jet Fuel - Transportation	Output
MPBLK_PKSAS	$1987/Btu	Census Regions, Years	Kerosene - All Sectors	Output
MPBLK_PKSCM	$1987/Btu	Census Regions, Years	Kerosene - Commercial	Output
MPBLK_PKSIN	$1987/Btu	Census Regions, Years	Kerosene - Industrial	Output
MPBLK_PKSRS	$1987/Btu	Census Regions, Years	Kerosene - Residential	Output
MPBLK_PLGAS	$1987/Btu	Census Regions, Years	Liquid Petroleum Gases - All Sectors	Output
MPBLK_PLGCM	$1987/Btu	Census Regions, Years	Liquid Petroleum Gases - Commercial	Output
MPBLK_PLGIN	$1987/Btu	Census Regions, Years	Liquid Petroleum Gases - Industrial	Output
MPBLK_PLGRS	$1987/Btu	Census Regions, Years	Liquid Petroleum Gases - Residential	Output
MPBLK_PLGTR	$1987/Btu	Census Regions, Years	Liquid Petroleum Gases - Transportation	Output
MPBLK_PMETR	$1987/Btu	Census Regions, Years	Methanol Transportation	Output
MPBLK_PMGAS	$1987/Btu	Census Regions, Years	Motor Gasoline - All Sectors	Output
MPBLK_PMGCM	$1987/Btu	Census Regions, Years	Motor Gasoline - Commercial	Output
MPBLK_PMGIN	$1987/Btu	Census Regions, Years	Motor Gasoline - Industrial	Output
MPBLK_PMGTR	$1987/Btu	Census Regions, Years	Motor Gasoline - Transportation	Output
MPBLK_PNGIN	$1987/Btu	Census Regions, Years	Natural Gas - Industrial	Input
MPBLK_POTAS	$1987/Btu	Census Regions, Years	Other Petroleum - All Sectors	Output
MPBLK_POTIN	$1987/Btu	Census Regions, Years	Other Petroleum - Industrial	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
MPBLK_POTTR	$1987/Btu	Census Regions, Years	Other Petroleum - Transportation	Output
MPBLK_PPFIN	$1987/Btu	Census Regions, Years	Petrochemical - Feedstock Industrial	Output
MPBLK_PRHAS	$1987/Btu	Census Regions, Years	Residential Fuel High Sulfur - All Sectors	Output
MPBLK_PRHEL	$1987/Btu	Census Regions, Years	Residential Fuel High Sulfur - Electricity	Output
MPBLK_PRHTR	$1987/Btu	Census Regions, Years	Residential Fuel High Sulfur - Transportation	Output
MPBLK_PRLAS	$1987/Btu	Census Regions, Years	Residential Fuel Low Sulfur - All Sectors	Output
MPBLK_PRLCM	$1987/Btu	Census Regions, Years	Residential Fuel Low Sulfur - Commercial	Output
MPBLK_PRLEL	$1987/Btu	Census Regions, Years	Residential Fuel Low Sulfur - Electricity	Output
MPBLK_PRLIN	$1987/Btu	Census Regions, Years	Residential Fuel Low Sulfur - Industrial	Output
MPBLK_PRLTR	$1987/Btu	Census Regions, Years	Residential Fuel Low Sulfur - Transportation	Output
MX_NCI_NCI	Dimension		Coal Supply Curves (Domes	Input
MX_NCL_NCL	Dimension		Domestic Coal Supply Curv	Input
MX_RNK _RNK	Dimension		Coal ranks	Input
MX_SO2_SO2	Dimension		SO2 Compliance Groups	Input
MXPBLK_XPALMG	$1987/b	Census Regions, Years	Expected UNLEADED AND REFORMULATED	Input
MXPBLK_XPELIN	$1987/Btu	Census Regions, Years	Purchased Electricity. Industrial	Input
MXPBLK_XPGIIN	$1987/Btu	Census Regions, Years	Natural Gas, Noncore. Industrial	Input
MXQBLK_XQASIN	tBtu	Census Regions, Years	Asphalt and Road Oil - Industrial	Input
MXQBLK_XQDSCM	tBtu	Census Regions, Years	Distillate - Commercial	Input
MXQBLK_XQDSEL	tBtu	Census Regions, Years	Distillate - Electricity (+petroleum coke)	Input
MXQBLK_XQDSIN	tBtu	Census Regions, Years	Distillate - Industrial	Input
MXQBLK_XQDSRS	tBtu	Census Regions, Years	Distillate - Residential	Input
MXQBLK_XQDSTR	tBtu	Census Regions, Years	Distillate - Transportation	Input
MXQBLK_XQETTR	tBtu	Census Regions, Years	Ethanol - Transporation	Input
MXQBLK_XQJFTR	tBtu	Census Regions, Years	Jet Fuel - Transportation	Input
MXQBLK_XQKSAS	tBtu	Census Regions, Years	Kerosene - All Sectors	Input
MXQBLK_XQLUIN	tBtu	Census Regions, Years	Lubricants - Industrial	Input
MXQBLK_XQMGAS	tBtu	Census Regions, Years	Motor Gasoline - All Sectors	Input
MXQBLK_XQNGTR	tBtu	Census Regions, Years	Natural Gas - Transportation	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
MXQBLK_XQOTIN	tBtu	Census Regions, Years	Other Petroleum - Industrial	Input
MXQBLK_XQOTRF	tBtu	Census Regions, Years	Other Petroleum - Refinery	Input
MXQBLK_XQPCAS	tBtu	Census Regions, Years	Petroleum Coke - All Sectors	Input
MXQBLK_XQPCRF	tBtu	Census Regions, Years	Petroleum Coke - Refinery	Input
MXQBLK_XQPFIN	tBtu	Census Regions, Years	Petrochemical Feedstocks - Industrial	Input
MXQBLK_XQRHAS	tBtu	Census Regions, Years	Residual Fuel, High Sulfur - All Sectors	Input
MXQBLK_XQRHEL	tBtu	Census Regions, Years	Residual Fuel, High Sulfur - Electricity	Input
MXQBLK_XQRLAS	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - All Sectors	Input
MXQBLK_XQRLEL	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Electricity	Input
MXQBLK_XQRLRF	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Refinery	Input
NCNTRL_CURCALYR			CURRENT CALENDAR YEAR	Input
NCNTRL_CURITR			CURRENT ITERATION	Input
NCNTRL_FCRL			FINAL CONVERGENCE AND REPORTING LOOP SWITCH (1=ON)	Input
NDREGN_	Dimension		Coal Demand Regions	Input
NDRGN1_	Dimension		NEMS coal demand regions - position 1 is national total	Input
NUMCGF_	Dimension		Number of combined heat a	Input
NUTSEC_	Dimension		Utility demand sectors	Input
OGDIST_	Dimension		OGSM districts	Input
OGSMOUT_OGCO2AVL	MMcf		CO2 available (MMcf) by Price Bin	Input
OGSMOUT_OGCO2PLF	$1987/MMcf		CO2 price from LFMM	Output
OGSMOUT_OGCO2PRC	$1987/MMcf		CO2 price ($/MMcf)	Input
OGSMOUT_OGCO2PUR2	MMcf		CO2 purchased at the EOR sites (MMcf)	Input
OGSMOUT_OGCO2QLF	MMcf		CO2 quantity from LFMM	Output
OGSMOUT_OGCO2TAR	$1987/MMcf		CO2 transport price from OGSM ($/MMcf)	Input
OGSMOUT_OGCRDHEAT	Btu/b	Crude Type, Years	Heat rates by crude oil type	Input
OGSMOUT_OGCRUDEREF	Mb/d	PADD Region, Crude Type, Years	Crude oil production by refinery region and crude	Input
OGSMOUT_OGNGPlbU	Mb	OGSM Districts, Years	Butane production from natural gas processing plan	Input
OGSMOUT_OGNGPLET	Mb	OGSM Districts, Years	Ethane production from natural gas processing plan	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
OGSMOUT_OGNGPLIS	Mb	OGSM Districts, Years	Isobutane production from natural gas processing p	Input
OGSMOUT_OGNGPLPP	Mb	OGSM Districts, Years	Pentanes plus production from natural gas processi	Input
OGSMOUT_OGNGPLPR	Mb	OGSM Districts, Years	Propane production from natural gas processing pla	Input
OGSMOUT_OGNGPLPRD	Mb	OGSM Districts, Years	Natural gas plant liquids by many regions	Input
PMMFTAB_ADVCAPCD	Mb/d	Census Regions, Years	Advanced ethanol plant capacity	Output
PMMFTAB_CBIODUAL		Year	Dual price from the biofuels offset row (CTRNBIO)	Output
PMMFTAB_CELLIMPFRAC	Fraction	Census Regions, Years	Fraction of ethanol imports that is cellulosic	Output
PMMFTAB_CLLCAPCD	Mb/d	Census Regions, Years	Cellulosic ethanol plant capacity	Output
PMMFTAB_CONEFF	Scalar	Year	gallon ethanol per short ton cellulose	Input
PMMFTAB_CRNCAPCD	Mb/d	Census Regions, Years	Corn ethanol plant capacity	Output
PMMFTAB_DSCSHR	Percent	Census Regions, Years	CARB diesel share of total ultra low diesel	Output
PMMFTAB_DSMURS	$1987/Btu	Census Regions, Years	1 = DISTRIBUTION MARKUP.. DS FUEL.. RESIDENTIAL Price	Output
PMMFTAB_DSMUTR	$1987/Btu	Census Regions, Years	PRICE 87$Btu 2 = TAX MARKUP..DS FUEL.. TRANSPORT	Output
PMMFTAB_E85ICCREDIT	$1987/b	Year	E85 infrastructure cost	Output
PMMFTAB_GRNCAPCD	Mb/d	Census Regions, Years	Grain ethanol plant capacity	Output
PMMFTAB_JFMUTR	$1987/Btu	Census Regions, Years	JET FUEL TRANSPORTATION	Output
PMMFTAB_LCFSSAFE		Year	Safety valve for the Biofuels constraint in 1000 t	Input
PMMFTAB_MGMUTR	$1987/Btu	Census Regions, Years	REFORMULATED - MARKUP - MOTOR GASOLINE TRANS	Output
PMMFTAB_MINREN	Mb/d	Year	Minimum renewable (including biodiesel CTL) in gasoline and diesel	Output
PMMFTAB_PAlbOB	$1987/b	Census Regions, Years	Wholesale BOB price	Output
PMMFTAB_PALMG	$1987/b	Census Regions, Years	ALL COMBINED (UNLEAD(REG+PREM) + REFORMULATED	Output
PMMFTAB_PDS	$1987/b	Census Regions, Years	PRICE DISTILLATE FUEL OIL --> PD	Output
PMMFTAB_PDSCRB	$1987/b	Census Regions, Years	CARB diesel price	Output
PMMFTAB_PDSL	$1987/b	Census Regions, Years	Distillate Subcategories	Output
PMMFTAB_PDSU	$1987/b	Census Regions, Years	Distillate Subcategories	Output
PMMFTAB_PJF	$1987/b	Census Regions, Years	PRICE JET FUEL	Output
PMMFTAB_PLMQTYCD	Mb/d	Census Regions, Years	New palm oil quantity	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
PMMFTAB_RFENVFX	$1987/Btu	Census Regions, Years	ENVIRONMENTAL FIXED COST - 20 PRODUCTS	Output
PMMFTAB_RFHCXH2IN	MMb/d	PADD Region, Years	Hydrogen from natural gas input to refinery	Output
PMMFTAB_RFIMPEXPEND	$1987/b	Year	Expenditures on imports	Output
PMMFTAB_RFQEL	MMb/d	Year	ELECTRIC POWER PRODUCT SUPPLIED	Input
PMMFTAB_RFQIN	MMb/d	Year	INDUSTRIAL PRODUCT SUPPLIED	Input
PMMFTAB_RFQNGPF	MMb/d	Census Regions, Years	TOTAL SECT.PRDS	Output
PMMFTAB_RFQRC	MMb/d	Year	RESIDENTIAL/COMMERCIAL PRODUCT SUPPLIED	Output
PMMFTAB_RFQSECT	MMb/d	Year	ALL SECTOR TOTAL PRODUCT SUPPLIED	Output
PMMFTAB_RFQTR	MMb/d	Year	TRANSPORTATION PRODUCT SUPPLIED	Output
PMMFTAB_SBO_PRICE	$1987/b	Census Regions, Years	Soybean oil price	Output
PMMFTAB_SBO2GDTPD	MMb/d	PADD Region, Years	Seed oil to GDT unit	Output
PMMFTAB_SBO2SAFPD	MMb/d	PADD Region, Years	Seed oil to SAF unit	Output
PMMFTAB_SBOQTYCD	Mb/d	Census Regions, Years	New seed oil quantity used to produce renewable diesel	Output
PMMFTAB_UBAVOLDS	Mb/d	PADD Region, Years	Pyrolysis liquid blended into diesel	Output
PMMFTAB_UBAVOLMG	Mb/d	PADD Region, Years	Pyrolysis liquid blended into mogas	Output
PMMFTAB_WGR_PRICE	$1987/b	Census Regions, Years	Other feedstock (white grease?) price	Output
PMMFTAB_WGR2GDTPD	MMb/d	PADD Region, Years	White grease to GDT unit	Output
PMMFTAB_WGR2SAFPD	MMb/d	PADD Region, Years	White grease to SAF unit	Output
PMMFTAB_WS_RBOB	$1987/b	Census Regions, Years	Wholesale RBOB price	Output
PMMFTAB_YGR_PRICE	$1987/b	Census Regions, Years	Yellow grease price	Output
PMMFTAB_YGR2GDTPD	MMb/d	PADD Region, Years	Yellow grease to GDT unit	Output
PMMOUT_BTLFRAC	Mb/d		BTL liquid produced by type	Output
PMMOUT_CBTLFRAC	MMb/d		Liquids produced from coal or biomass combo plant (1 if by coal 2 if by biomass)	Output
PMMOUT_CRNPRICE	$1987/Bu	Census Regions, Years	Price of corn	Output
PMMOUT_CTLFRAC	Mb/d		CTL liquid produced by type	Output
PMMOUT_DCRDWHP	$1987/b	Oil & Gas Regions, Years	DOMESTIC CRUDE WELLHEAD PRICE	Input
PMMOUT_ETHNE85	Fraction		Fraction ethanol makes up of E85	Output
PMMOUT_GlbCRDDMD	MMb/d	Year	World crude oil demand (PMM results)	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
PMMOUT_GTLFRAC	MMb/d		Liquids from gas by type	Output
PMMOUT_OS_WOP	$1987/b	Year	Shale Oil Price Paid by refiners in 2008 dollars	Input
PMMOUT_PRDSTKWDR	MMb/d	PADD Region, Years	Petroleum product stock withdrawal	Input
PMMOUT_QBMRFBTL	tBtu	Census Regions, Years	Biomass for BTL	Output
PMMOUT_QCLRFPD	tBtu	PADD Region, Years	Coal for CTL	Output
PMMOUT_QMERF	tBtu	Census Regions, Years	Methanol purchased by refineries	Output
PMMOUT_RFPQNGL	MMb/d	PADD Region, Years	PRICE-QUANITY OF NGL BY PADD FOR 6 NGL'S	Output
PMMOUT_RFQDCRD	MMb/d		DOMESTIC TOTAL CRUDE MMBBL/YR/OGSM	Input
PMMOUT_RFQNGPL	Mb/d	PADD Region, Years	Quantity of streams from natural gas processing plants	Output
PMMOUT_RFQPRCG	MMb/d	PADD Region, Years	Refinery processing gain	Output
PMMOUT_RFQPRDT	MMb/d	Census Regions, Years	TOTAL PRODUCT SUPPLIED	Output
PMMOUT_RFSPRFR	MMb/d	Year	SPR withdrawals	Output
PMMOUT_RFSPRIM	MMb/d	Year	SPR IMPORTS	Input
PMMOUT_TRGNE85	Fraction		Fraction traditional gasoline makes up of E85	Output
PMMOUT_UBAVOL	Mb/d	PADD Region, Years	Pyrolysis liquid produced	Output
PMMOUT_XDCRDWHP	$1987/b	Oil & Gas Regions, Years	EXPECTED DOMESTIC CRUDE WELLHEAD PRICE	Input
PMMOUT_XRFQDCRD	$1987/b	Oil & Gas Regions, Years	EXPECTED DOMESTIC CRUDE PRODUCTION	Input
PMMOUT_XTL_CO2AVAIL	MMton	PADD Region, Years	CO2 fr xTL (less 15% to atm) avail for sequestration	Output
PMMRPT_BIMQTYCD	Mb/d		Biodiesel production by type and census	Output
PMMRPT_BIODCONCD	Mb/d		Biodiesel consumption by virgin or non	Output
PMMRPT_BIODEXP	Mb/d	Census Regions, Years	Biodiesel exports by census	Output
PMMRPT_BIODIMP	Mb/d	Census Regions, Years	Biodiesel imports by census	Output
PMMRPT_BIODPRICE	$1987/b	Census Regions, Years	Biodiesel price	Output
PMMRPT_BLDIMP	MMb/d	PADD Region, Years	BLENDING IMPORTS	Output
PMMRPT_CLLETHCD	Mb/d	Census Regions, Years	ETHANOL PRODUCED FROM CELLULOSE	Output
PMMRPT_CRNETHCD	Mb/d	Census Regions, Years	ETHANOL PRODUCED FROM CORN	Output
PMMRPT_ETHE85CD	MMb/d	Census Regions, Years	Ethanol for E85 at Census division level	Output
PMMRPT_ETHEXP	Mb/d	Census Regions, Years	Ethanol exports	Output
PMMRPT_ETHIMP	Mb/d	Census Regions, Years	Ethanol imports	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
PMMRPT_ETHTOTCD	MMb/d	Census Regions, Years	Total ethanol production by census	Output
PMMRPT_GRNETHCD	Mb/d	Census Regions, Years	Non-corn non-advanced ethanol produced from grain	Output
PMMRPT_MUFTAX	$1987/Btu	Year	FEDERAL TAXES - 15 PRODUCTS	Output
PMMRPT_OTHETHCD	Mb/d	Census Regions, Years	Ethanol produced from other feedstock	Output
PMMRPT_PETHANOL	$1987/b	Census Regions, Years	Ethanol blending value	Output
PMMRPT_PETHM	$1987/b	Census Regions, Years	Marginal ethanol price	Output
PMMRPT_QPRDEX	Mb/d	Exported Products, Years	Exports by product	Output
PMMRPT_RFBDSTCAP	MMb/d	PADD Region, Years	REF BASE DISTILLATION CAPACITY	Input
PMMRPT_RFCRDOTH	Mb/d	PADD Region, Years	OTHER CRUDE INPUTS BY PADD & YR	Output
PMMRPT_RFDSTCAP	MMb/d	PADD Region, Years	REFINERY DISTILLATION CAPACITY	Output
PMMRPT_RFDSTUTL	MMb/d	PADD Region, Years	CAPACITY UTILIZATION RATE	Output
PMMRPT_RFETHE85	MMb/d	PADD Region, Years	QUANTITY E85	Output
PMMRPT_RFIMCR	MMb/d	PADD Region, Years	1 Crude net imports	Output
PMMRPT_RFIMTP	MMb/d	PADD Region, Years	2 Total prod net imports	Output
PMMRPT_RFIPQCLL	Mb/d	PADD Region, Years	IMPORT CRUDE-LO SULFUR LT(P . Q)	Output
PMMRPT_RFMETI	MMb/d	PADD Region, Years	IMPORTED METHANOL	Output
PMMRPT_RFMETM85	MMb/d	PADD Region, Years	QUANT M85	Output
PMMRPT_RFMTBI	MMb/d	PADD Region, Years	IMPORTED MTBE	Output
PMMRPT_RFPQIPRDT	MMb/d	PADD Region, Years	TOTAL PRODUCT IMPORTED	Output
PMMRPT_RFPQUFC	MMb/d	PADD Region, Years	TOTAL IMPORTS OF UNFINISHED REF MOD OUTPUT COMM	Output
PMMRPT_RFQARO	MMb/d	Census Regions, Years	QUANTITY OF ASPHALT AND ROAD OIL	Output
PMMRPT_RFQDS	MMb/d	Census Regions, Years	DISTILLATE FUEL OIL --> QDSAS (MNUMCR . MNUMYR)	Output
PMMRPT_RFQEXCRD	MMb/d	PADD Region, Years	CRUDE EXPORTED	Output
PMMRPT_RFQEXPRDT	MMb/d	PADD Region, Years	PRODUCT EXPORTS	Output
PMMRPT_RFQICRD	MMb/d	PADD Region, Years	IMPORTED TOTAL CRUDE MMBBLD per PADD	Output
PMMRPT_RFQJF	MMb/d	Census Regions, Years	JET FUEL --> QJFTR(MNUMCR . MNUMYR)	Output
PMMRPT_RFQKS	MMb/d	Census Regions, Years	KEROSENE --> QKSAS(MNUMCR . MNUMYR)	Output
PMMRPT_RFQLG	MMb/d	Census Regions, Years	LPG --> QLGAS(MNUMCR . MNUMYR)	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
PMMRPT_RFQMG	MMb/d	Census Regions, Years	REFORMULATED	Output
PMMRPT_RFQOTH	MMb/d	Census Regions, Years	OTHER --> QOTAS (MNUMCR . MNUMYR)	Output
PMMRPT_RFQPCK	MMb/d	Census Regions, Years	QUANTITY OF PETROLEUM COKE	Output
PMMRPT_RFQPF	MMb/d	Census Regions, Years	PETROCHEMICAL FEED STOCKS --> QPFIN (CR.YR)	Output
PMMRPT_RFQRH	MMb/d	Census Regions, Years	RESIDUAL FUEL OIL HIGH SULFUR --> QRHAS(CR.YR)	Output
PMMRPT_RFQRL	MMb/d	Census Regions, Years	RESIDUAL FUEL OIL LOW SULFUR --> QRLAS (CR.YR)	Output
PMMRPT_RFQSTG	MMb/d	Census Regions, Years	QUANTITY OF STILL GAS	Output
PMMRPT_TDIESEL	Mb/d	Census Regions, Years	Total diesel consumption	Output
PMORE_PBUIN	$1987/Btu	Census Regions, Years	Butane - Industrial	Output
PMORE_PBUINPF	$1987/Btu	Census Regions, Years	Butane feedstock - Industrial	Output
PMORE_PETIN	$1987/Btu	Census Regions, Years	Ethane - Industrial	Output
PMORE_PETINPF	$1987/Btu	Census Regions, Years	Ethane feedstock - Industrial	Output
PMORE_PISIN	$1987/Btu	Census Regions, Years	Isobutane - Industrial	Output
PMORE_PISINPF	$1987/Btu	Census Regions, Years	Isobutane - Feedstock Industrial	Output
PMORE_PLUIN	$1987/Btu	Census Regions, Years	Lubricants - Industrial	Output
PMORE_PPCIN	$1987/Btu	Census Regions, Years	Industrial petroleum coke	Input
PMORE_PPPIN	$1987/Btu	Census Regions, Years	Pentanes plus - Industrial	Output
PMORE_PPPINPF	$1987/Btu	Census Regions, Years	Pentanes plus - Feedstock Industrial	Output
PMORE_PPRCM	$1987/Btu	Census Regions, Years	Propane - Commercial	Output
PMORE_PPRIN	$1987/Btu	Census Regions, Years	Propane - Industrial	Output
PMORE_PPRINPF	$1987/Btu	Census Regions, Years	Propane feedstock - Industrial	Output
PMORE_PPROLENERF		Census Regions, Years	Propylene - Refinery production	Output
PMORE_PPRRS	$1987/Btu	Census Regions, Years	Propane - Residential	Output
PMORE_PPRTR	$1987/Btu	Census Regions, Years	Propane - Transportation	Output
PMORE_PSULFURIN		Census Regions, Years	Sulfur - Industrial	Output
PONROAD_PDSTRHWY	$1987/MMBtu	Census Regions, Years	On-road distillate price transportation secto	Output
PRDEXP_	Dimension		Maximum number of exported products	Output
QBLK_QASIN	tBtu	Census Regions, Years	Asphalt and Road Oil - Industrial	Input
QBLK_QBMRF	tBtu	Census Regions, Years	Biomass - Refinery Use	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
QBLK_QCLRF	tBtu	Census Regions, Years	Purchased Coal - Refinery	Output
QBLK_QDSCM	tBtu	Census Regions, Years	Distillate - Commercial	Input
QBLK_QDSEL	tBtu	Census Regions, Years	Distillate - Electricity (+petroleum coke)	Input
QBLK_QDSIN	tBtu	Census Regions, Years	Distillate - Industrial	Input
QBLK_QDSRS	tBtu	Census Regions, Years	Distillate - Residential	Input
QBLK_QDSTR	tBtu	Census Regions, Years	Distillate - Transportation	Input
QBLK_QELAS	tBtu	Census Regions, Years	Purchased Electricity - All Sectors	Input
QBLK_QELRF	tBtu	Census Regions, Years	Purchased Electricity - Refinery	Output
QBLK_QETTR	tBtu	Census Regions, Years	Ethanol - Transportation	Input
QBLK_QH2RF	tBtu	Census Regions, Years	Market H2 consumption in refineries by census dvision	Output
QBLK_QJFTR	tBtu	Census Regions, Years	Jet Fuel - Transportation	Input
QBLK_QKSAS	tBtu	Census Regions, Years	Kerosene - All Sectors	Input
QBLK_QKSCM	tBtu	Census Regions, Years	Kerosene - Commercial	Input
QBLK_QKSIN	tBtu	Census Regions, Years	Kerosene - Industrial	Input
QBLK_QKSRS	tBtu	Census Regions, Years	Kerosene - Residential	Input
QBLK_QLGAS	tBtu	Census Regions, Years	Liquid Petroleum Gases - All Sectors	Input
QBLK_QLGRF	tBtu	Census Regions, Years	LPG - Refinery Use	Output
QBLK_QLGTR	tBtu	Census Regions, Years	Liquid Petroleum Gases - Transportation	Input
QBLK_QMGAS	tBtu	Census Regions, Years	Motor Gasoline - All Sectors	Input
QBLK_QMGCM	tBtu	Census Regions, Years	Motor Gasoline - Commercial	Input
QBLK_QMGIN	tBtu	Census Regions, Years	Motor Gasoline - Industrial	Input
QBLK_QMGTR	tBtu	Census Regions, Years	Motor Gasoline - Transportation	Input
QBLK_QNGRF	tBtu	Census Regions, Years	Purchased Natural Gas - Refiner	Output
QBLK_QNGTR	tBtu	Census Regions, Years	Natural Gas - Transportation	Input
QBLK_QOTAS	tBtu	Census Regions, Years	Other Petroleum - All Sectors	Input
QBLK_QOTIN	tBtu	Census Regions, Years	Other Petroleum - Industrial	Input
QBLK_QOTRF	tBtu	Census Regions, Years	Other Petroleum - Refinery Use	Output
QBLK_QOTTR	tBtu	Census Regions, Years	Other Petroleum - Transportation	Input
QBLK_QPCAS	tBtu	Census Regions, Years	Petroleum Coke - All Sectors	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
QBLK_QPCIN	tBtu	Census Regions, Years	Petroleum Coke - Industrial	Input
QBLK_QPCRF	tBtu	Census Regions, Years	Petroleum Coke - Refinery Use	Output
QBLK_QPFIN	tBtu	Census Regions, Years	Petrochemical Feedstocks - Industrial	Input
QBLK_QRHAS	tBtu	Census Regions, Years	Residual Fuel, High Sulfur - All Sectors	Input
QBLK_QRHEL	tBtu	Census Regions, Years	Residual Fuel, High Sulfur - Electric Power	Input
QBLK_QRHTR	tBtu	Census Regions, Years	Residual Fuel, High Sulfur - Transportation	Input
QBLK_QRLAS	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - All Sectors	Input
QBLK_QRLCM	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Commercial	Input
QBLK_QRLEL	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Electric Power	Input
QBLK_QRLIN	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Industrial	Input
QBLK_QRLRF	tBtu	Census Regions, Years	Low-sulfur Residual Fuel - Refinery Use	Output
QBLK_QRLTR	tBtu	Census Regions, Years	Residual Fuel, Low Sulfur - Transportation	Input
QBLK_QSGRF	tBtu	Census Regions, Years	Still Gas - Refinery Use	Output
QMORE_QBUIN	tBtu	Census Regions, Years	Industrial butane	Input
QMORE_QBURF	tBtu	Census Regions, Years	Butane - Refinery Use	Output
QMORE_QETIN	tBtu	Census Regions, Years	Industrial ethane	Input
QMORE_QETINPF	tBtu	Census Regions, Years	Industrial ethane feedstock	Input
QMORE_QISIN	tBtu	Census Regions, Years	Industrial isobutane	Input
QMORE_QISRF	tBtu	Census Regions, Years	Isobutane - Refinery Use	Output
QMORE_QLUIN	tBtu	Census Regions, Years	Industrial lubricants	Input
QMORE_QPPIN	tBtu	Census Regions, Years	Industrial pentanes plus	Input
QMORE_QPRCM	tBtu	Census Regions, Years	Commercial propane	Input
QMORE_QPRIN	tBtu	Census Regions, Years	Industrial propane	Input
QMORE_QPROLENERF	lb	Census Regions, Years	Refinery production of propylene	Input
QMORE_QPRRF	tBtu	Census Regions, Years	Propane - Refinery Use	Output
QMORE_QPRRS	tBtu	Census Regions, Years	Residential propane	Input
QMORE_QPRTR	tBtu	Census Regions, Years	Transportation propane	Input
QMORE_QPYRF	tBtu	Census Regions, Years	Propylene - Refinery Use	Output
QONROAD_CFDSTRHWY	MMBtu/b	Year	On-road distillate conversion factor trans. Sector	Output

Restart Variable	Unit	Dimension Name	Description	Input or Output
QONROAD_QDSTRHWY	tBtu	Census Regions, Years	On-road distillate quantity transportation sector	Output
QSBLK_QSDSCM	tBtu	Census Regions, Years	Distillate - Commercial	Input
QSBLK_QSDSIN	tBtu	Census Regions, Years	Distillate - Industrial	Input
QSBLK_QSDSRS	tBtu	Census Regions, Years	Distillate - Residential	Input
QSBLK_QSDSTR	tBtu	Census Regions, Years	Distillate - Transportation	Input
QSBLK_QSJFTR	tBtu	Census Regions, Years	Jet Fuel - Transportation	Input
QSBLK_QSLGCM	tBtu	Census Regions, Years	Liquid Petroleum Gases - Commercial	Input
QSBLK_QSLGIN	tBtu	Census Regions, Years	Liquid Petroleum Gases - Industrial	Input
QSBLK_QSLGRS	tBtu	Census Regions, Years	Liquid Petroleum Gases - Residential	Input
QSBLK_QSLGTR	tBtu	Census Regions, Years	Liquid Petroleum Gases - Industrial	Input
QSBLK_QSMGCM	tBtu	Census Regions, Years	Motor Gasoline - Commercial	Input
QSBLK_QSMGIN	tBtu	Census Regions, Years	Motor Gasoline - Industrial	Input
QSBLK_QSMGTR	tBtu	Census Regions, Years	Motor Gasoline - Transportation	Input
REFREG_	Dimension		Refinery Regions	Input
TCS45Q_CCS_EOR_45Q	$/ton	Years	45Q tax credit for enhanced oil recovery	Input
TCS45Q_CCS_SALINE_45Q	$/ton	Years	45Q tax credit for saline injection	Input
TCS45Q_I_ 45Q_LYR_NEW	Years		End year of tax code section 45Q subsidy for new builds	Input
TRANREP_E85AVAIL	Fraction	Census Regions, Years	E85 Availability - Percent Stations with E85 Capability	Output
TRANREP_FCLOGIT0	Scalar	Census Regions	Fuel price logit term	Input
TRANREP_FCLOGIT1	Scalar		Fuel price logit term	Input
TRANREP_FCLOGIT2	Scalar		Fuel availability logit constant	Input
TRANREP_FCLOGIT3	Scalar		Fuel availability logit term	Input
TRANREP_FCLOGIT4	Scalar		Fuel price logit term	Input
TRANREP_QAGTR	tBtu	Census Regions, Years	Aviation gasoline demand	Input
TRANREP_QFFV	tBtu	Census Regions, Years	Total flex fuel vehicle energy demand by region	Input
TRANREP_QLUTR	tBtu	Census Regions, Years	Lubricants demand	Input
TRANREP_TRQLDV	tBtu		Lt Duty Vehicle Energy Use	Input
TRANREP_XQAGTR	tBtu	Census Regions, Years	Expected aviation gasoline demand	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
TRANREP_XQFFV	tBtu	Census Regions, Years	Total flex fuel vehicle energy demand by region	Input
TRANREP_XQLUTR	tBtu	Census Regions, Years	Expected lubricants demand	Input
TRANREP_XTRQLDV	tBtu		Lt Duty Vehicle Energy Use for expectation years	Input
UECPOUT_FR_OR_TRANCOST		Max Number of EMM Fuel Regions	Unit Co2 trsnport costs from each fuel regi	Input
UECPOUT_MUST_STORE		Max Number of EMM Fuel Regions, Years	Indicates that captured CO2 must be stored in sali	Input
UECPOUT_TnS_Costs		Max Number of EMM Fuel Regions, Years	Unit Co2 trsnport and storage costs in each	Input
UEFPOUT_PElb	$1987/Btu	Census Regions, Years	Marginal energy price of base load generation	Input
USO2GRP_CTL_CDSL1		Coal Demand Region, Refinery Region	Maps Coal Demand to Refinery Regions	Input
USO2GRP_CTL_CLDR		Coal Demand Region	CTL Coal Demand Regions (0 => No CTL Demand in the	Input
USO2GRP_CTL_OTHER	tBtu	Domestic Coal Supply Curves, Years	Expected Coal Demand for Non - Coal to Liquids - C	Input
USO2GRP_CTL_TRATE	tBtu	Domestic Coal Supply Curves, Coal Demand Region	Expected Coal Transportation Rates for Coal to Liq	Input
USO2GRP_CTL_TYPE		Domestic Coal Supply Curves	CTL Coal Type by Coal Supply Curve	Input
USO2GRP_EFD_RANK		Coal Supply Curves	EFD Coal Rank Indicator	Input
USO2GRP_XCL_1TESC		Domestic Coal Supply Curves, Years in Full ECP Planning Horizon, Years, Coal Demand Region	Expected Coal Transportation Escalation Factors	Input
USO2GRP_XCL_2TESC		Domestic Coal Supply Curves, Years in Full ECP Planning Horizon, Years, Coal Demand Region	Expected Coal Transportation Escalation Factors	Input
USO2GRP_XCL_HG	MMton/quad	Coal Supply Curves	Mercury Content by Supply Curve	Input
USO2GRP_XCL_MX_PCAP		Domestic Coal Supply Curves	Maximum Rate of Increase in Production Capacity	Input
USO2GRP_XCL_PCAP	tBtu	Domestic Coal Supply Curves, Years	Current Year Coal Supply Production Capacity	Input
USO2GRP_XCL_PECP	$1987/Btu	Domestic Coal Supply Curves	Expected Coal Supply Prices by ECP Step	Input
USO2GRP_XCL_QECP	tBtu	Domestic Coal Supply Curves, Years in Full ECP Planning Horizon, Years	Expected Coal Supply Quantities	Input
USO2GRP_XCL_SO2	lb/Btu	Coal Supply Curves	SO2 Content by Supply Curve	Input
USO2GRP_XCL_STEPS	Dimension		Expected Coal Supply Step Definitions	Input
WDCRVS_	Dimension		WRENEW parameter: number	Input
WRENEW_CRNSUP_ETH_Q	MMBu		Polysys Corn Supply Used for Ethanol	Input
WRENEW_CRNSUP_P	$1987/Btu		Polysys Price of Corn	Input
WRENEW_CRNSUP_TOT_Q	MMBu		Polysys Total Corn Supply	Input
WRENEW_MP_BM_BT		Number of Wood Supply Curve Types	Map Applicable Supply Types for Biomass to Liquids	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
WRENEW_MP_BM_CM		Number of Wood Supply Curve Types	Map Applicable Supply Types for Commercial Sector	Input
WRENEW_MP_BM_ET		Number of Wood Supply Curve Types	Map Applicable Supply Types for Cellulosic Ethanol	Input
WRENEW_MP_BM_H2		Number of Wood Supply Curve Types	Map Applicable Supply Types for Hydrogen Productio	Input
WRENEW_MP_BM_IN		Number of Wood Supply Curve Types	Map Applicable Supply Types for Non-Refinery Indus	Input
WRENEW_MP_BM_PW		Number of Wood Supply Curve Types	Map Applicable Supply Types for Electric Power Sec	Input
WRENEW_MP_BM_RS		Number of Wood Supply Curve Types	Map Applicable Supply Types for Residential Sector	Input
WRENEW_QBMBTCL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	BTL Production Demand for Biomass used from the supply curves	Output
WRENEW_QBMET	tBtu	Census Regions, Years	Biomass consumed to make ethanol	Input
WRENEW_QBMETCL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	Ethanol Production Demand for Biomass used from the supply curves	Output
WRENEW_QBMH2CL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	Biomass Demand in Hydrogen Production Sector	Input
WRENEW_QBMINCL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	Biomass Demand in Non-Refinery Industrial Sector	Input
WRENEW_QBMPWCL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	Biomass Demand in Electric Power Sector	Input
WRENEW_QBMRSCL	tBtu	Number of Wood Supply Curve Types Plus Total, Coal Demand Regions, Years	Biomass Demand in Residential Sector	Input
WRENEW_QCLETH	tBtu	Census Regions, Years	Purchased Coal - Ethanol plants	Output
WRENEW_QELETH	tBtu	Census Regions, Years	Purchased Electricity - Ethanol plants	Output
WRENEW_QNGETH	tBtu	Census Regions, Years	Purchased Natural Gas - Ethanol plants	Output
WRENEW_SOYOILSUP_BIOD_Q	MMlb		Polysys Soyoil supply used for biodiesel	Input
WRENEW_SOYOILSUP_P	$1987/lb		Polysys Price of Soyoil	Input
WRENEW_SOYOILSUP_TOT_Q	MMlb		Polysys Total Soyoil Supply	Input
WRENEW_SOYSUP_P	$1987/Bu		Polysys Price of Soybeans	Input
WRENEW_SOYSUP_TOT_Q	MMBu		Polysys Total Soybeans Supply	Input
WRENEW_WDSUP_P_AG	$1987/Btu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Prices - Agricultural Waste	Input
WRENEW_WDSUP_P_EC	$1987/Btu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Prices - Energy Crops	Input
WRENEW_WDSUP_P_FR	$1987/Btu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Prices - Forestry Residue	Input

Restart Variable	Unit	Dimension Name	Description	Input or Output
WRENEW_WDSUP_P_UM	$1987/Btu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Prices - Urban Wood Waste	Input
WRENEW_WDSUP_Q_AG	tBtu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Quantities - Agricultural Waste	Input
WRENEW_WDSUP_Q_EC	tBtu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Quantities - Energy Crops	Input
WRENEW_WDSUP_Q_FR	tBtu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Quantities - Forestry Residue	Input
WRENEW_WDSUP_Q_UM	tBtu	Wood Supply Curve Steps, Coal Demand Region, Years	Biomass Supply Quantities - Urban Wood Waste	Input