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PETROLEUM MARKET MODEL OF THE NATIONAL ENERGY MODELING SYSTEM

Part 1 – Report and Appendix A

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Oil and Gas Division
Office of Integrated Analysis and Forecasting
Energy Information Administration

The Petroleum Market Model (PMM) of the National Energy Modeling System is developed and maintained by the Energy Information Administration (EIA), Office of Integrated Analysis and Forecasting. General questions about the use of the model can be addressed to James Kendell (202) 586-9646, Director of the Oil and Gas Division. Specific questions concerning the PMM may be addressed to:

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This report documents the archived version of the PMM that was used to produce the petroleum forecasts presented in the *Annual Energy Outlook 2003*, (DOE/EIA-0383(2003)). The purpose of this report is to provide a reference document for model analysts, users, and the public that defines the objectives of the model, describes its basic approach, and provides detail on the methodology employed. The model documentation is updated annually to reflect significant model methodology and software changes that take place as the model develops. The next version of the documentation is planned to be released in the first quarter of 2004.

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Acronyms and Abbreviations

AEO	EIA Annual Energy Outlook
API	American Petroleum Institute
ASTM	American Society of Testing Materials
BAU	Business As Usual
bbl	Barrel
bbl/cd	Barrels Per Calendar Day
Bcf	Billion cubic feet
Btu	British thermal unit
BTX	Benzene, Toluene, and Xylene Aromatics
BPSD	Barrels Per Stream Day
CAAA	Clean Air Act Amendments
CARB	California Air Resources Board
CD	Census Division
CG	Conventional Gasoline
Cn	Represents a hydrocarbon stream containing n atoms of Carbon, i.e. C1 is Methane, C2 is Ethane, C3 is Propane, C4 is Butane, etc.
CTL	Coal-To-Liquids (Converting coal through syngas to diesel-grade blending streams)
DOE	Department of Energy
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
ETBE	Ethyl Tertiary Butyl Ether
FCC	Fluid Catalytic Cracker
GWh	Gigawatthour
GTL	Gas-To-Liquids (Converting natural gas through syngas to diesel-grade blending streams)
IEA	International Energy Agency
IEO	EIA International Energy Outlook
KWh	Kilowatthour
LP	Linear Programming
LPG	Liquefied Petroleum Gas
Mbbl/cd	Thousand Barrels Per Calendar Day
Mbtu	Thousand British Thermal Units
Mcf	Thousand cubic feet
MMbbl/cd	Million Barrels Per Calendar Day
MMbtu Million	British Thermal Units
MTBE	Methyl Tertiary Butyl Ether
NACOD	North American Crude Oil Distribution
NEMS	National Energy Modeling System
NES	National Energy Strategy
NGL	Natural Gas Liquid
NIPER	National Institute for Petroleum and Energy Research
NOx	Nitrogen Oxide
NPC	National Petroleum Council
NPRA	National Petroleum Refiners Association
OB1	Optimization with Barriers 1
OML	Optimization and Modeling Libraries
ORNL	Oak Ridge National Laboratory

OVC	Other Variable Costs
PADD	Petroleum Administration for Defense District
PCF	Petrochemical Feed
PMM	Petroleum Market Model
RFG	Reformulated Gasoline
RFS	Renewable Fuels Standard (optional for regulatory analysis purposes)
RVP	Reid Vapor Pressure
RYM	Refinery Yield Model (EIA)
SCF	Standard Cubic Feet
SIC	Standard Industrial Classification
SPR	Strategic Petroleum Reserve
Syngas	Gaseous products from hydrocarbons (e.g., natural gas, petroleum coke, or coal) reacting with steam/O_2, mostly consisting of CO and H_2
TAP	Toxic Air Pollutant
ULSD	Ultra-Low-Sulfur Diesel
VOC	Volatile Organic Compound
WOP	World Oil Price
WORLD	World Oil Refining Logistics Demand (model)

1. Introduction

1.1 Purpose of this Report

The purpose of this report is to define the objectives of the Petroleum Market Model (PMM), describe its basic approach, and provide detail on how it works. This report is intended as a reference document for model analysts, users, and the public. 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). This volume documents the version of the PMM used for the *Annual Energy Outlook 2003* (*AEO2003*) and thus supersedes all previous versions of the documentation.

1.2 Model Summary

The PMM models petroleum refining activities, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol and ethanol production. The PMM projects petroleum product prices and sources of supply for meeting petroleum product demand. The sources of supply include crude oil, both domestic and imported; other inputs including alcohols and ethers; natural gas plant liquids production; petroleum product imports; unfinished oil imports, and refinery processing gain. In addition, the PMM estimates domestic refinery capacity expansion and fuel consumption. Product prices are estimated at the Census Division level and much of the refining activity information is at the Petroleum Administration for Defense District (PADD) level.

1.3 Model Archival Citation

The PMM is archived as part of the National Energy Modeling System for *AEO2003*. The model contact is:

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1.4 Report Organization

The remainder of this report is organized as follows: Chapter 2, Model Purpose; Chapter 3, Model Overview and Rationale; Chapter 4, Model Structure; Appendix A, PMM Data and Outputs; Appendix B, Mathematical Description of Model; Appendix C, Bibliography; Appendix D, Model Abstract; Appendix E, Data Quality; Appendix F, Estimation Methodologies; Appendix G, Matrix Generator Documentation; Appendix H, Historical Data Processing; and Appendix I, Ethanol Supply Model.

2. Model Purpose

2.1 Model Objectives

The Petroleum Market Model (PMM) models petroleum refining and marketing. The purpose of the PMM is to project petroleum product prices, refining activities, and movements of petroleum into the United States and among domestic regions. In addition, the PMM estimates capacity expansion and fuel consumption in the refining industry. The PMM is also used to analyze a wide variety of petroleum-related issues and policies, in order to foster better understanding of the petroleum refining and marketing industry and the effects of certain policies and regulations.

The PMM simulates the operation of petroleum refineries in the United States,[1] including the supply and transportation of crude oil to refineries, the regional processing of these raw materials into petroleum products, and the distribution of petroleum products to meet regional demands. The production of natural gas liquids from gas processing plants, and the production of diesel-grade blending streams from either natural gas (gas-to-liquids, or GTL) in Alaska or from coal (coal-to-liquids, or CTL), are also represented. The essential outputs of this model are product prices, a petroleum supply/demand balance, demands for refinery fuel use, and capacity expansion.

PMM inputs include petroleum product demands, domestic crude oil production levels, and information on the costs and available quantities of imports of crude oil and petroleum products. In addition, the costs of refinery inputs such as natural gas and electricity are needed, as well as the costs and available quantities of blending components such as ethanol, methanol, and methyl tertiary butyl ether (MTBE). Yield coefficients for crude oil distillation and other processing units, processing unit capacities, investment costs for capacity additions, capacities and costs for pipeline and other transportation modes, and product specifications are other essential model inputs.

From these inputs, PMM produces a slate of prices for petroleum products, the quantity of domestic crude oil production, imports of crude oil and petroleum products, estimates of other refinery inputs and processing gain, domestic refinery capacity expansion, and refinery fuel consumption.

The PMM is used to represent the petroleum refining and marketing sector in projections published in the *Annual Energy Outlook*. The model is also used for analysis of a wide variety of petroleum-related issues. The PMM is able to determine the impact on refinery operations and on the marginal costs of refined products of changes in any one or several variables including demands for various kinds of petroleum products; crude oil prices; refinery processing unit capacities; changes in certain petroleum product specifications; energy policies and regulations; and taxes, tariffs, and subsidies. Since *AEO2002*, the

[1]The International Energy Model contains representation for foreign refinery operations.

model has been enhanced to analyze the various provisions of proposed Energy Bills in the 107th Congress, including a possible nationwide MTBE ban and a Renewable Fuels Standard (RFS). A coal-to-liquids representation was also added in response to a request from the DOE Office of Fossil Energy.

The PMM is comprised of three geographical regions, defined using the five Petroleum Administration for Defense Districts (PADD's). Individual refineries in PADD I are aggregated into one refinery representation for region 1. Region 2 is an aggregate of all refineries operating in PADD's II, III, and IV. PADD V refineries are represented by a single refinery in region 3. Product demands are input at the Census Division level and end-use product prices are produced by Census Division. A transportation structure linking the PADD refining regions to the Census Division demand regions is also represented. The PMM produces annual results, currently from 1995 through 2025.

2.2 Relationship to Other Models

The PMM is part of the National Energy Modeling System (NEMS), representing the petroleum refining and marketing sector. The PMM projects prices and sources of supplies of petroleum products. These projections are generated as part of a NEMS supply/demand/price equilibrium solution.

Several other models in NEMS provide inputs to the PMM. These inputs include:

- Demands for petroleum products from the Residential, Commercial, Industrial, Transportation, and Electricity Market Models. The demands include motor gasoline, jet fuel, kerosene, heating oil, low- and ultra-low-sulfur diesel fuels, low- and high-sulfur residual fuel, liquefied petroleum gases (LPG), petrochemical feedstocks, petroleum coke, and other petroleum.

- Import supply curves for crude oil and petroleum products from the International Energy Model (IEM). The crude oil supply curves are provided for each of the PAD Districts for five types of crude defined by sulfur and gravity characteristics. The prices on the crude oil supply curves are based on the world oil price, which is determined in the IEM. Petroleum product import supply curves are provided for conventional and reformulated gasoline, heating oil, low- and ultra-low-sulfur diesel fuels, jet fuel, low- and high-sulfur residual fuel, LPG, petrochemical feedstocks, and other petroleum. This information is used to evaluate the tradeoff between domestic product production and imports.

- Import supply curves for methanol and MTBE provided by the International Energy Model. The use of methanol and ethanol in the PMM takes into account the consumption of alcohol fuels in the transportation sector (E85 and M85), and the chemical use of methanol.

- Domestic crude oil production levels from the Oil and Gas Supply Model (OGSM). The crude oil is categorized into the same five types incorporated into the import supply curves. Natural gas liquids, which are among the non-crude inputs to refineries, are estimated using natural gas production from the Natural Gas Transmission and Distribution Model (NGTDM).

- Prices for natural gas and electricity from the NGTDM and the Electricity Market Model (EMM), respectively. The PMM estimates the refinery consumption of these energy sources.

- The market shares of oxygenated, reformulated, conventional, and California specification gasoline. These parameters are estimated offline and input to the PMM. In a similar fashion, the shares of low- and ultra-low-sulfur diesel fuels and heating oil are provided to the PMM. The shares change over time, based on assumptions about market penetration (see Appendix F for more details), and applicable regulations such as the Ultra-Low-Sulfur Diesel (ULSD) Rule starting in June 2006. By breaking gasoline and distillate into these categories, the PMM is able to account for additional costs of producing products that meet Clean Air Act (CAA) and Clean Air Act Amendments (CAAA) requirements.

- Cellulosic feedstock prices and quantities for the Renewable Fuels Module.

The PMM also provides information to other NEMS models. The output variables include petroleum product prices, petroleum supply sources, refinery fuel consumption, and capacity expansion.

Output variables include:

- Prices of petroleum products, passed to the Residential, Commercial, Industrial, Transportation, Electricity Market, and Natural Gas Transmission and Distribution Models. The prices are used to estimate demands for the various fuels.

- Supply balance quantities, including crude oil production, non-crude refinery inputs, and processing gain, provided for reporting purposes.

- Capacity expansion and utilization rates at refineries (mainly for reporting purposes).

- Fuel consumption from refineries. This information is passed on to the Industrial Model for inclusion in the industrial sector totals. In addition, refinery cogeneration capacity and generation levels are also sent to the Industrial Model.

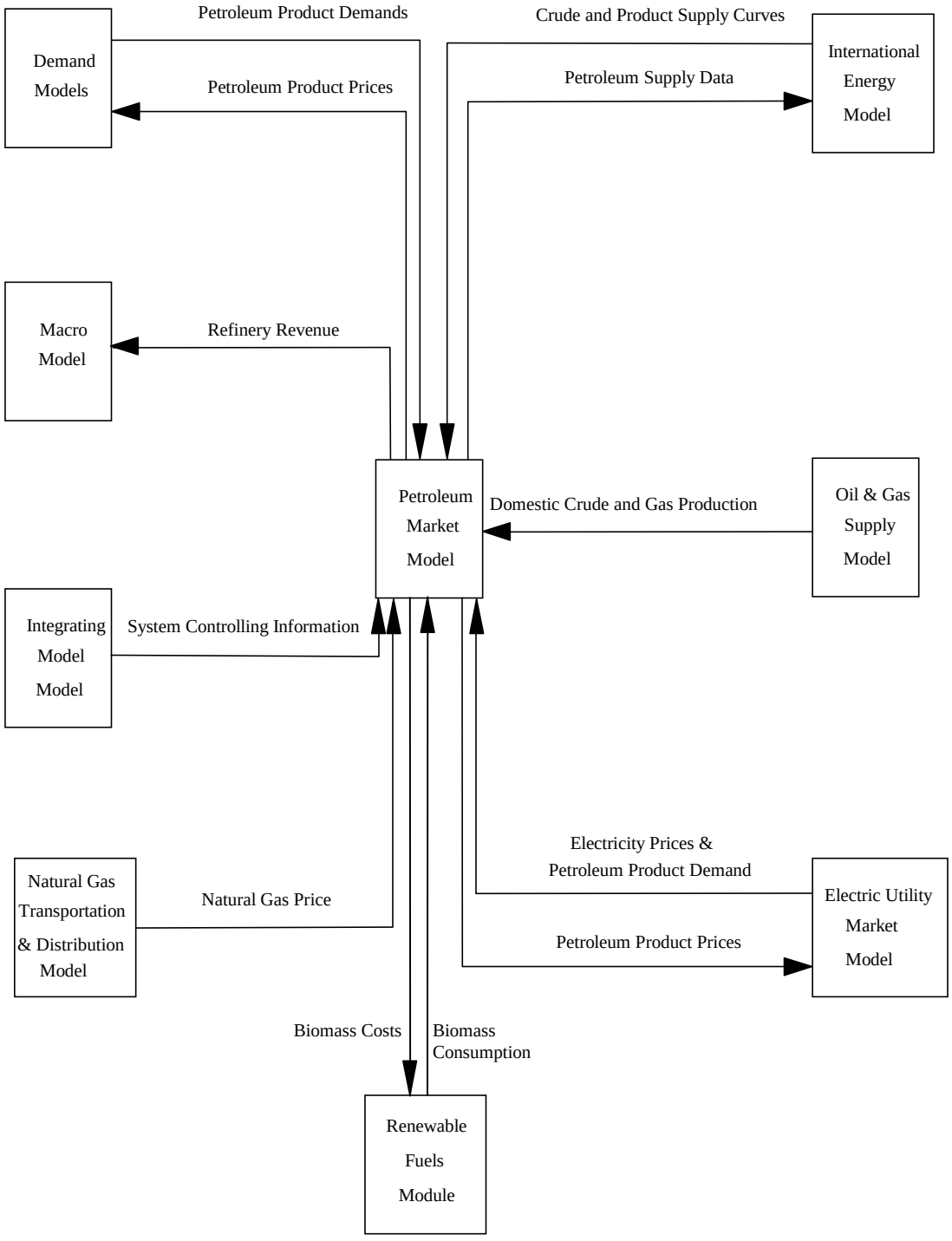
- The amount of sulfur allowances earned by small refiners, as described in the CAAA.

- The market prices and consumption of ethanol and methanol.

- Cellulosic feedstock consumption.

Figure 2.1 provides a detailed PMM Input/Output flow diagram.

Figure 2.1 PMM Input - Output Flow Diagram



3. Model Overview and Rationale

3.1 Theoretical Approach

The National Energy Modeling System, as a whole, produces a general equilibrium solution by iterating until convergence to a stable result. For example, the various demand models use the petroleum product prices from PMM to estimate product demands. The PMM then takes the petroleum product demands as given, and estimates petroleum product prices. If the computed prices from PMM converge to within the specified tolerance, the NEMS iteration is complete and the next yearly NEMS cycle begins. If the computed prices have not converged, new demand quantities are computed, passed to PMM, and the cycle is repeated. This process continues until a stable solution is found.

Within the PMM, the refinery sector is modeled by a linear programming representation. A linear programming model is developed for three refining regions. The first region consists of Petroleum Administration for Defense District (PADD) I; the second of PADD's II, III, and IV; and the third of PADD V. Each model region represents an aggregation of the individual refineries in the region. The PMM linear programming model also contains a transportation structure to move products from the refining regions to the Census Division demand regions. Because a single demand region can be supplied by more than one refining region (if the transportation connections exist), changes in one refining region can affect operations in other refining regions. An optimal solution for the three representations together is found by minimizing the costs of meeting the demands. Revenues are derived from product sales, and costs are incurred from the purchase and processing of raw materials and the transportation of finished products to the market. The model chooses a set of petroleum industry activities (e.g. crude oils, processing units, etc.) to produce a product mix that maximizes the refinery's economic benefits. The activities are constrained by material balance requirements on the crude oil and intermediate streams, product specifications, processing and transportation capacities, and demand. Economic forces also govern the decision to import crude oil or refined products into the regions. See Appendix B for a complete description of the column activities and constraints.

The three-region linear program formulation has been used since 1997. Prior to that the PMM utilized a five-region linear program, with each region representing a PAD District. In an effort to reduce the size and run time of the PMM, the number of refining regions was reduced from five to three. The regions were formulated to maximize analytical relevance. Region 1 remains unchanged as a representation of PAD District I. PAD District I is maintained as a separate refining region because of its unique product import characteristics. PAD Districts II, III, IV were consolidated to form Region 2, and PAD District V is modeled in Region 3. PAD District V remains a separate refining region because of the stricter blending requirements of California gasolines.

3.2 Comparison with Oil Market Module

The inclusion of a linear programming model directly into the integrated refining and marketing representation is a significant change from predecessor models. The Oil Market Module (OMM), which represented petroleum refining and marketing in the Intermediate Future Forecasting System, used econometric equations to represent the relationship between refinery production costs (product costs) and product yields. The econometric equations were estimated from pseudo-data derived from a refinery linear programming model. Pseudo-data were developed by running a refinery LP for hundreds of scenarios where the yield of a reduced set of petroleum products was recorded in response to independently varying product prices over a predefined range. This was done for a base case and three representative world oil prices (WOP). Additionally, a number of runs ultimately were made where prices of all products were simultaneously increased for each WOP. In total, nearly 400 runs were made to create the pseudo-data. An accounting/econometric framework was used to estimate sources of supply to meet demand. Product imports were calculated as the difference between demand and domestic supply.

The decision to change the approach for PMM within NEMS resulted from the identification of several disadvantages for using the OMM approach.[1]

- The econometric equations produce only national-level refinery gate (or wholesale) prices for the product slate defined, with regional end-use prices being estimated from predefined regionally specific distribution cost characteristics. Thus, regional differences in input costs or product specifications were not being reflected in the results since regional production levels were not represented.

- Product imports were used as balancing items, thus preventing both a realistic assessment of import dependence and a realistic analysis of import restrictions or tariffs.

- The OMM could not model changes in product specifications such as those included in the Clean Air Act Amendments (CAAA).

- The OMM lacked the capability to decide between domestic and foreign capacity expansion efforts. This was an important decision activity directly affecting import levels.

[1]Energy Information Administration, *A Critique of the Oil Market Module*, internal study by S. MacIntyre, Energy Supply and Conversion Division, Office of Integrated Analysis and Forecasting (Washington, DC, January 1992).

- The OMM could not be used to analyze the impact of requiring oxygenates in gasoline and the competition between oxygenates.

In addition, any changes to refinery operating scenarios within OMM (whether significant or minor) would involve a three-step process -- (1) modify the linear programming model to reflect the changes, (2) rerun the LP model to generate new pseudo-data (involving several hundred runs), and (3) re-estimate the econometric equation coefficients. This is a resource-intensive process.

3.3 Fundamental Assumptions

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

The PMM represents three refining regions: the first region consisting of PADD I; the second of PADD's II, III, and IV; and the third of PADD V. Each refining region is treated as a single firm. This restricts the ability to deal with issues such as rationalization of small refineries. Rationalization can only be dealt with on a disaggregate basis. Capacity is allowed to expand, with some limitations, but the model does not distinguish between additions to existing refineries or the building of new facilities. Investment criteria are developed exogenously, although the decision to invest is endogenous. The model does not require foresight to be perfect, but uses the best available information concerning future prices, demands, and market conditions as the basis for investment decisions.

Existing regulations concerning product types and specifications, the cost of environmental compliance, and Federal and State taxes are also modeled in the PMM.[2] The PMM reflects recent national and regional legislative and regulatory changes that will affect future petroleum supply and product prices. It incorporates taxes imposed by the 1993 Budget Reconciliation Act and the 1997 Tax Payer Relief Act as well as costs resulting from the Clean Air Act Amendments (CAAA) of 1990 and other environmental legislation.

The costs of producing new formulations of gasoline and diesel fuel that are required by State and Federal regulations are determined within the linear programming (LP) representation by incorporating specifications and demands for these fuels. The PMM assumes that the specifications for gasoline will

[2] The PMM is an annual model. Thus, product specifications are modeled as annual averages, rather than taking into account the seasonal variations (particularly for gasoline specifications).

remain the same as specified in current legislation, except that the sulfur content of all gasoline will be phased-down to 30 ppm to reflect new regulations published by EPA in February 2000.[3] The PMM includes a new type of ultra-low-sulfur-diesel (ULSD) in order to model highway diesel regulations finalized by EPA in December 2000.[4] Proposed fuel changes can be modeled by changing the specifications used by the PMM.

Motor Gasoline Specifications

The PMM models the production and distribution of four different types of gasoline: conventional, oxygenated, reformulated (Phase 2), and CARB gasoline. The following specifications are included in the PMM to differentiate between conventional and reformulated gasoline blends: octane, oxygen content, Reid Vapor Pressure (RVP), benzene content, aromatic content, sulfur content, olefin content, and the percent evaporated at 200 and 300 degrees Fahrenheit (E200 and E300).

The sulfur specification for gasoline is reduced to reflect recent regulations requiring the average annual sulfur content of all gasoline used in the United States to be phased-down to 30 ppm between the years 2004 and 2007. PMM assumes that RFG has an average annual sulfur content of 135 ppm in 2000 and will meet the 30 ppm requirement in 2004. The reduction in sulfur content between now and 2004 is assumed to reflect incentives for "early reduction." The regional assumptions for phasing-down the sulfur in conventional gasoline account for less stringent sulfur requirements for small refineries and refineries in the Rocky Mountain region. The 30 ppm annual average standard is not fully realized in conventional gasoline until 2008 due to allowances for small refineries.

The specifications for conventional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of conventional gasoline from eroding over time, which is the intent of the EPA's "antidumping" requirements.

Oxygenated gasoline, which has been required during winter in many U.S. cities since October of 1992, requires an oxygen content of 2.7 percent by weight. Oxygenated gasoline is assumed to have specifications identical to conventional gasoline with the exception of a higher oxygen requirement. Some areas that require oxygenated gasoline will also require reformulated gasoline. For the sake of simplicity, the areas of overlap are assumed to require gasoline meeting the reformulated specifications.

Reformulated gasoline has been required in many areas of the United States since January 1995. Beginning in 1998, the EPA has certified reformulated gasoline using the "Complex Model," which allows refiners to specify reformulated gasoline based on emissions reductions either from their companies' 1990

[3]U.S. EPA, *"Tier2" Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements*, February 2000, Washington, D.C.

[4]U.S. EPA, "Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements: Final Rule," *Federal Register*, 40 CFR Parts 69, 80, and 86 (January 18, 2001).

baseline or from the EPA's 1990 baseline. The PMM reflects "Phase 2" of the Complex Model requirements which began in 2000. The PMM uses a set of specifications that meet the Complex Model requirements, but it does not attempt to determine the optimal specifications that meet the Complex Model. The State of California currently uses its own set of performance-based gasoline standards instead of the Federal Complex Model standards. The PMM assumes that all West Coast refiners must meet the current California Air Resources Board "CARB2" requirements until 2004 when a new set of "CARB3" requirements will take their place. The CARB3 standards were designed to complement the State's plans to ban the oxygenate, methyl tertiary butyl ether (MTBE), by the end of 2003.[5] Because MTBE is currently the main source of oxygen for gasoline in the State, California petitioned the EPA for a waiver to the Federal RFG oxygen requirement. Because the waiver request was denied by EPA, PMM reflects no oxygen waiver in the four areas of California covered by the Federal reformulated gasoline program: Los Angeles, San Diego, Sacramento, and San Joaquin Valley. RFG in these areas is classified in the PMM as "RFG" while CARB gasoline without an oxygen requirement is classified as "RFH."

AEO2003 reflects legislation which bans or limits the use of MTBE in 16 additional States: Arizona, Colorado, Connecticut, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Missouri, Nebraska, Ohio, New York, South Dakota, and Washington.[6] Since the oxygen requirement on RFG is assumed to continue in these States, the MTBE ban is modeled as a requirement to produce ethanol blended RFG.

Arizona also has a reformulated gasoline program for the Phoenix area which is mandated by State law. Phoenix had previously been part of the Federal RFG program but opted out when State requirements were adopted. Phoenix is required to use CARB gasoline in the winter but may use either CARB or Federal RFG in the summer. Arizona is in a different model region than California and, for the sake of simplicity, is assumed to use RFG meeting Federal specifications.

RVP limitations are effective during summer months, which are defined differently in different regions. In addition, different RVP specifications apply within each refining region, or PAD district. The PMM assumes that these variations in RVP are captured in the annual average specifications, which are based on summer RVP limits, winter RVP estimates, and seasonal weights.

Motor Gasoline Market Shares

Within the PMM, total gasoline demand is disaggregated into demand for conventional, oxygenated, and reformulated gasolines by applying assumptions about the annual market shares for each type. Annual

[5]CARB 3 standards were originally planned for the end of 2002, along with the ether ban in California. In March 2002, Gov. Davis issued an executive order to postpone the ether ban and the phase-in of CARB 3 gasoline to the end of 2003. For further information, see http://www.arb.ca.gov/cbg/carfg3/carfg3.htm.

[6]Because legislation in Maine reflects a "goal" of phasing out MTBE rather than an enforceable mandate, a ban in Maine is not included in *AEO2003* assumptions.

assumptions for each region account for the seasonal and city-by-city nature of the regulations. The market shares are assumed to remain constant at the 2001 level, with minor adjustments reflecting known changes in oxygenated or reformulated gasoline programs.

In Census Division 9, 74 percent of gasoline is assumed to be reformulated. Starting in 2004 when MTBE is banned in California, this set of reformulated gasoline is broken out into two groups: CARB gasoline that does not require oxygen and gasoline in the four areas of California covered by the Federal reformulated gasoline program (Los Angeles, San Diego, Sacramento, and San Joaquin Valley) which will continue to require 2.0 percent oxygen. The market shares assume that 59 percent of the gasoline in Census Division 9 will continue to meet the Federal 2.0 percent oxygen requirement, and 15 percent will meet CARB with no oxygen requirement.

Although the shares are assumed to remain constant after 2004, the PMM structure allows for them to change over time based alternative assumptions about the market penetration of new fuels. This allows for flexibility to analyze the impact of differing market share assumptions and to adjust the assumptions over time based on updated information about announced participation in the oxygenated and reformulated gasoline programs.

Diesel Fuel Specifications and Market Shares

In order to account for CAAA90 diesel desulfurization regulations, current highway-grade diesel is differentiated from other distillates. Diesel fuel in Census Divisions 1 through 8 is assumed to meet Federal specifications including a maximum sulfur content of 500 parts per million (ppm) and a maximum aromatic content of 35 percent by volume.[7] Diesel fuel in Census Division 9 is assumed to meet California Air Resources Board (CARB) standards which limit sulfur content to 500 ppm and aromatics to 10 percent by volume.[8]

A second type of highway diesel has been incorporated in PMM in order to model the "ultra-low-sulfur diesel" (ULSD) regulation finalized in December 2000. By definition ultra-low-sulfur diesel is highway diesel that contains no more than 15 parts per million of sulfur at the pump. The regulation contains an "80/20" rule which requires the production of 80 percent ULSD and 20 percent 500 ppm highway diesel between June 2006 and June 2010, and a 100 percent requirement for ULSD thereafter. Because NEMS is an annual average model, the full impact of the 80/20 rule cannot be seen until 2007 and the impact of the 100 percent requirement cannot be seen until 2011. Major assumptions related to the implementation of the ULSD rule are provided below:

[7]Federal regulations require either a maximum 35 percent (volume) aromatics or a cetane index of 40.

[8]http://www.arb.ca.gov/fuels/diesel/diesel.htm

Demand for highway-grade diesel, both 500 and 15 ppm combined, is assumed to be equivalent to the total transportation distillate demand. Historically, highway-grade diesel supplied has nearly matched total transportation distillate sales although some of the highway-grade diesel went to non-transportation uses such as construction and agriculture.

Highway diesel at the refinery gate is assumed to contain a maximum of 7 ppm sulfur. Although sulfur content is limited to 15 ppm at the pump, there is a general consensus that refineries will need to produce diesel somewhat below 10 ppm in order to allow for contamination during the distribution process.

End-Use Product Prices

End-use petroleum product prices are based on marginal costs of production plus production-related fixed costs plus distribution costs and taxes. The marginal costs of production are determined by the model and represent variable costs of production including additional costs for meeting Tier 2 gasoline and ULSD regulations. Environmental costs associated with controlling pollution at refineries[9] are reflected as fixed costs. Assuming that refinery-related fixed costs are recovered in the prices of light products, fixed costs are allocated among the prices of liquefied petroleum gases, gasoline, distillate, kerosene, and jet fuel. These costs are based on average annual estimates and are assumed to remain constant over the forecast period.

The costs of distributing and marketing petroleum products are represented by adding fixed distribution costs to the marginal and refinery fixed costs of products. The distribution costs are applied at the Census Division level and are assumed to be constant throughout the forecast and across scenarios. Distribution costs for each product, sector, and Census Division represent average historical differences between end-use and wholesale prices. The costs for kerosene are the average difference between end-use prices of kerosene and wholesale distillate prices. Additional distribution costs are added to the historical average diesel costs to account for increase capital and operating costs related to ULSD requirements. End-use prices also include a variable which calibrates model results to historical levels. The calibration variable is specified by product and region.

State and Federal taxes are also added to transportation fuels to determine final end-use prices. Tax trend analysis indicated that State taxes increase at the rate of inflation, while Federal taxes do not.[10] In the PMM, therefore, State taxes are held constant in real terms throughout the forecast while Federal taxes are deflated at the rate of inflation. An average local tax of 2 cents per gallon is also assumed to remain constant in real terms.[11]

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[9]Environmental cost estimates are based on National Petroleum Council, *U.S. Petroleum Refining – Meeting Requirements for Cleaner Fuels and Refineries*, Volume I (Washington, DC, August 1993).

[10] Energy Information Administration, *Issues in Midterm Analysis and Forecasting 1998 – Motor Fuels Tax Trends and Assumptions*, by Stacy Macintyre.

[11]American Petroleum Institute, How Much We Pay For Gasoline: 1997 Annual Review, page 4 (Washington, DC, April 1998).

Crude Oil Quality

In the PMM, the quality of crude oil is characterized by average gravity and sulfur levels. Both domestic and imported crude oil are divided into five categories as defined by the ranges of gravity and sulfur shown in Table A2 in Appendix A. A composite crude oil with the appropriate yields and qualities is developed for each category by averaging the characteristics of specific crude oil streams that fall into each category. While the domestic and foreign crude types have the same definitions, the composite crude oils for each category may differ because different crude streams make up the composites. For domestic crude oil, an estimate of total production is made first, then shared out to each of the five categories based on historical data. For imported crude oil, a separate supply curve is provided for each of the five categories.

Regional Assumptions

The PMM represents three refining regions. The first refining region includes only Petroleum Administration for Defense District (PADD) I, while the second, includes PADD's II, III, and IV, and the third includes PADD V. Individual refineries are aggregated into one linear programming representation for each region. In order to interact with other NEMS modules with different regional representations, certain PMM inputs and outputs are converted from a PMM region to a non-PMM regional structure and vice versa.

Capacity Expansion Assumptions

PMM allows for capacity expansion of all processing units including distillation capacity, vacuum distillation, hydrotreating, coking, fluid catalytic cracking, hydrocracking, alkylation, and methyl tertiary butyl ether (MTBE) manufacture. Capacity expansion occurs by processing unit, starting from base year capacities established from historical data for each region. Expansion of the atmospheric crude unit (ACU) is limited to 2.25 million barrels per day in each refining region through 2025.

Expansion is determined when the value received from the additional product sales exceeds the investment and operating costs of the new unit. The investment costs in *AEO2003* assume a 10-percent hurdle rate in the decision to invest and a 10-percent rate of return over a 15-year plant life. These variables may be adjusted for sensitivity analysis, and the assumed hurdle rate and the rate of return may be different.

Capacity expansion is done in 3-year increments. For example, the PMM looks ahead in 2002 and determines the optimal capacities given the expected demands and prices for the 2005 forecast year. The PMM then allows one-third of that capacity to be built in each of the forecast years 2003, 2004, and 2005. At the end of 2005, the cycle begins anew, looking ahead to 2008.

Strategic Petroleum Reserve Fill Rate

The PMM assumes no additions for the Strategic Petroleum Reserve during the forecast period. Any SPR draw is assumed to be in the form of a swap with a zero net annual change.

Legislation

The PMM reflects recent national and regional legislative and regulatory changes that will affect future petroleum supply and product prices. It incorporates taxes imposed by the 1993 Budget Reconciliation Act and the 1997 Tax Payer Relief Act, as well as costs resulting from environmental legislation.

The Budget Reconciliation Act imposes a tax increase of 4.3 cents per gallon on transportation fuels including gasoline, diesel, liquefied petroleum gases, and jet fuel. The tax has been in effect since October 1, 1993, for all fuels but jet fuel. Onset of the jet fuel tax was delayed until 1996.

The Tax Payer Relief Act of 1997 reduced excise taxes on liquefied petroleum gases and methanol produced from natural gas. The reductions set taxes on these products equal to the Federal gasoline tax in terms of energy content (in Btu's).

With a goal of reducing tailpipe emissions in areas failing to meet Federal air quality standards (nonattainment areas), Title II of the CAAA90 established regulations for gasoline formulation. Starting in November 1992, gasoline sold during the winter in 39 carbon monoxide nonattainment areas was required to be oxygenated.[12] Starting in 1995, gasoline sold in major U.S. cities which are the most severe ozone nonattainment areas must be reformulated to reduce volatile organic compounds (which contribute to ozone formation) and toxic air pollutants, as well as meet a number of other new specifications. Additional areas with less severe ozone problems have chosen to "opt- in" to the reformulated gasoline requirement. Since 1998 reformulated gasoline has been required to meet a performance based definition, "the Complex Model." The more stringent "Phase II" Complex Model performance measures have been in effect since January 2000.

Title II of the CAAA90 also established regulations on the sulfur and aromatics content of diesel fuel that took effect on October 1, 1993. All diesel fuel sold for use on highways now contains less sulfur and meets new aromatics or cetane level standards.

"Tier2" Motor Vehicle Emissions Standards and Gasoline Sulfur Control Requirements were finalized by EPA in February 2000. This regulation requires that the average annual sulfur content of all gasoline used in the United States be phased-down to 30 ppm between the years 2004 and 2007. The 30 ppm annual

[12]Oxygenated gasoline must contain an oxygen content of 2.7 percent by weight.

average standard is not fully realized in conventional gasoline until 2008 due to allowances for small refineries.

Regulations requiring the highway use of "ultra-low-sulfur diesel" (ULSD) were finalized in December 2000. By definition ULSD is highway diesel that contains no more than 15 ppm sulfur at the pump. The new regulation contains an "80/20" rule, which requires the production of 80 percent ULSD and 20 percent 500 ppm highway diesel between June 2006 and June 2010, and a 100 percent requirement for ULSD thereafter.

The Federal Highway Bill of 1998 extended the current tax credit for ethanol through 2007 but stipulated that the 53 cents per gallon credit be reduced to 52 cents in 2003, and 51 cents in 2005. The PMM reflects an assumption that the credit will be extended at the nominal level of 51 cents per gallon through 2025.

A number of pieces of legislation are aimed at controlling air, water, and waste emissions from refineries themselves. The PMM incorporates related environmental investments as refinery fixed costs. The estimated expenditures are based on results of the 1993 National Petroleum Council Study.[13] These investments reflect compliance with Titles I, III, and V of CAAA90, the Clean Water Act, the Resource Conservation and Recovery Act, and anticipated regulations including the phase out of hydrofluoric acid and a broad-based requirement for corrective action. No costs for remediation beyond the refinery site are included.

The Congressional legislative process for a comprehensive energy bill had been under way since *AEO2002*; yet no final legislation was passed before *AEO2003* projections were finalized. The PMM was enhanced, nevertheless, to allow for consideration of several provisions in the Senate energy bill, primarily the renewable fuels standard (RFS) and the MTBE ban, and has been used for several related studies.[14] Because no formal energy legislation has been passed by the Congress, none of the provisions of the pending energy bill was incorporated in the forecast for *AEO2003*.

[13]National Petroleum Council, *U.S. Petroleum Refining - Meeting Requirements for Cleaner Fuels and Refineries*, Volume I (Washington, DC, August 1993).

[14]EIA, *Summary – Analysis of Selected Transportation Fuel Issues Associated with Proposed Energy Legislation*, October 23, 2002 (http://tonto.eia.doe.gov/FTPROOT/service/summary.pdf); *Impact of Renewable Fuels Standard/MTBE Provisions of S.1766*, March 2002 (http://www.eia.doe.gov/oiaf/servicerpt/mtbe/pdf/sroiaf(2002)06.pdf); and *Impact of Renewable Fuels Standard/MTBE Provisions of S. 517 Requested by Senators Daschle and Murkowski*, April 2002 (http://tonto.eia.doe.gov/FTPROOT/service/sroiaf(2002)07.pdf).

3.4 Alternative Approaches and Reasons for Selection

In any model design a tradeoff must be made between finding an acceptable level of detail and preserving a manageable framework for providing information in a timely fashion. The PMM was developed not only for forecasting purposes, but also to provide a policy analysis tool. These dual objectives were key to deciding the approach taken in the PMM. Various alternatives are discussed below followed by a summary of the reasons for choosing the linear programming approach.

3.4.1 Pseudo-data/Econometric Equation Approach

The OMM, as described above, used a pseudo-data/econometric equation approach. The objective of this approach was to retain the advantages of a large, complex refinery model, with the capability of responding to a wide variety of issues, in an integrated environment. The response surface generated by the large number of model runs represented the output of the LP for given sets of inputs, and the econometric equations provide a means to quickly access the results.

Two primary problems with this approach were inaccuracy and preparation time. The model runs must be devised so that the pseudo-data adequately cover the range of each of the inputs. Since the exact combination of inputs cannot usually be anticipated, the pseudo-data only provide an approximation of the model response. Moreover, the econometric equations are only an approximation of the shape of the response surface.

Preparation time (i.e., the time required before the model is ready for integrated runs) can be significant for this approach. The design, the generation of pseudo-data, and the estimation of the equations all require substantial time and effort. The OMM equations were re-estimated only about once every 4 years. However, because NEMS is used for analytical studies as well as mid-range forecasting, re-estimation of the equations would have been required for each particular study.

In addition, the capabilities of the PMM, compared to the OMM, especially the increased regionality, the explicit treatment of imports, and the new products and product specifications, would increase considerably the number of runs required to adequately cover the range of each input variable. For these reasons, the pseudo-data/econometric equation approach was not considered as a basis for PMM.

3.4.2 Linear Approximation Approach

Another type of pseudo-data approach, called the linear approximation or lookup approach, was considered. Pseudo-data would still need to be generated. The output of several hundred model runs would be placed in a database, with each record containing the refinery output quantities and prices associated with a given set of product demand levels and input prices. The runs would cover the expected range of product demands and input prices.

In the integrated environment, the inputs to the PMM (a vector of demands and input prices) would be used to choose a specified number of data records (e.g. 10) from the database. The data records chosen would be those (10) that minimized the Euclidean distance to the input data vector. The output quantities and prices would then be estimated from a linear combination of the chosen set of data records.

Several advantages over the OMM approach are noteworthy. The econometric equations would not need to be re-estimated with each new set of pseudo data, considerably reducing model preparation time. Furthermore, the output variables could include more than just product prices. Any variable generated by the use of an LP model could be placed in the database and accessed by the linear approximation method.

However, the same pseudo-data criticisms cited above apply to this method as well. Any study or scenario involving unanticipated changes to the refinery operating scheme would require regeneration of several hundred data records using a detailed model. In addition, the number of required runs would rise above the roughly 400 used in the past, due to regionality and the increased interactions between PMM and other models. The number of runs must be sufficient to adequately cover the expected range of each input variable, so it increases substantially with each additional input. Also, the accuracy of this method relative to the other approaches has not been established, but is considered to be less accurate than even the pseudo-data/econometric equation approach.[15]

[15]Energy Information Administration, *Approaches to Estimating PMM*, internal memorandum by J. Kendell, Energy Supply and Conversion Division, Office of Integrated Analysis and Forecasting (Washington, D.C., November 1991).

3.4.3 Abbreviated Linear Programming Approach

Extreme point modeling is similar to the pseudo-data approach in that a detailed model is used to generate output vectors. The results of each run are expressed as column vectors of input/output coefficients derived over a range of cases designed to span the potential solution space.[16]

A linear programming refinery model can be appreciably condensed through the technique of extreme point vectors. The extreme point representation models the refinery as series of operating modes or plans. A slate of products is produced per barrel of processed crude oil. An illustration of two typical extreme point vectors is shown in Table 3.1. Each column of the table represents an operating mode for the refinery, such as maximum production of gasoline or distillate (No. 2 heating oil and diesel fuel). For each solution of the detailed refinery model, the crude oils consumed as inputs are divided by the total crude oil processed to provide a volume fraction of each crude oil, which will sum to 1.0 as shown in the row labeled "Total Crude." Each solution also provides the product volumes produced as outputs, which are also divided by the total crude oil processed. After accounting for fuel burned and losses, not shown in the table, the sum of the outputs will also sum to 1.0. The result is a representation of a feasible and optimal operating plan expressed as inputs and outputs per barrel of total crude oil processed by the refinery model. Extreme point vectors typically have less than 50 equations for each refining region, including crude oil balance equations, refinery unit capacity equations, and product balance equations.

The operating modes, such as maximum gasoline and maximum distillate, are created by successive solutions of the detailed refinery model responding to increased prices for the product to be maximized. Some typical modes to be generated may be:

- maximum/minimum production of each grade of gasoline
- maximum/minimum production of jet fuel,
- maximum/minimum production of No. 2 heating oil,
- maximum/minimum production of low sulfur highway diesel fuel, or
- maximum/minimum production of residual fuel oil.

The extreme point representations can be expanded to differentiate between various crude oil operating modes, such as incremental volumes of Arab Light or incremental volumes of West Texas Intermediate (WTI).

[16]Linear Programming, Inc., *PAL/REMS Integration Methodology Study*, final report prepared for the EIA Office of Statistical Standards, Contract No. DE-AC01-84EI-19633 (Washington, D.C., April 1987).

Table 3.1. Example of Extreme Point Vectors
Yields per Barrel of Total Crude Flow

Mode	Max Gasoline	Max Distillate
Crude 1	0.5	0.5
Crude 2	0.2	0.2
Sum Other Crudes	0.3	0.3
Total Crude	1.0	1.0
Gasoline Grade 1	0.14	0.10
Gasoline Grade 2-5	0.35	0.25
No. 2 Heating Oil	0.14	0.30
Resid. <1%S	0.09	0.10
Sum of Other Products	0.28	0.25
Operating Cost ($/bbl)	0.94	1.00

The difference from the pseudo-data approach is that these vectors are then placed in a linear programming environment. The extreme points are not just output quantities and prices from the LP model runs, as in the pseudo-data approach, but coefficients which break input quantities into outputs of products, taking into account the associated costs. Solutions are derived by maximizing profits or minimizing costs using linear combinations of these extreme point column vectors to represent the refinery LP. A second important difference is that the required amount of extreme points numbers in the tens rather than the hundreds.

The advantage of using extreme point vectors to represent refining operations is that the resulting model is smaller and solves faster than a detailed refinery model. The disadvantage is that the analyst must create enough extreme points to span most of the possible modes and product yields that might be required in an equilibrium pricing model such as NEMS. Moreover, extreme points should probably be regenerated for each new forecast and each particular analytical study. This would be a time-consuming process. Extreme

points have also been criticized for inaccurately representing refinery operations,[17] although increasing the range and number of the modes can respond in part to this criticism.

3.4.4 Detailed Linear Programming Approach

Detailed linear programming models have been very successful at modeling refinery problems. The particular advantage of using linear programming models to represent refinery processes is that they allow refinery managers to calculate the marginal costs of products while simultaneously indicating the required operating conditions for maximum profitability. Furthermore, linear programming process models contain detailed engineering structure directly related to the refinery processes and product quality, and can therefore readily incorporate new technologies and technological change.

A linear programming approach in the PMM allows more flexibility for dealing with analytical issues than the other approaches considered. Changes to product specifications, the addition of new products or refinery inputs, and/or changes in processing unit costs or capacities can be handled directly in the linear programming structure. Many of the shortcomings of the pseudo-data and extreme point approaches are not problems for a linear programming approach. The biggest drawbacks to LP models are size and execution time. In 1997 the PMM was reduced from a five region (PAD) representation to a three region representation. The condensed regionality achieved more rapid execution times while still providing the capability for regional analysis.

[17]Ibid., pp. 25-39.

4. Model Structure

During each NEMS iterative solution, product demand quantities and other variables supplied by the other NEMS demand and supply models are used to update the PMM linear programming (LP) matrix. An optimal solution is obtained from the updated LP matrix where marginal petroleum product prices and other material balance information are extracted. Post-processing takes place on the petroleum product prices and refinery input and output volumes, system variables are updated, and reports are produced. The modification and optimization of the PMM LP matrix are both accomplished by executing FORTRAN callable LP subroutines available from a LP subroutine library. Appendix B describes the formulation of the linear programming representation in the PMM.

The linear programming portion of PMM is prepared offline in the form of an MPS[1] file prior to NEMS processing. Offline generation of the PMM matrix is performed using a data-driven mathematical programming language. The control program and optimizer are compatible with the MPS matrix format. FORTRAN and FORTRAN callable subroutines for data table manipulation, matrix generation, and solution retrieval programs for report writing are currently being used. Appendix A describes the input data tables used to develop the input LP matrix of the PMM. Appendix G documents the LP matrix generator source code and data tables.

The REFINE subroutine is the main controlling subroutine for the PMM. The following paragraph describes the REFINE process flow, which is illustrated by Figures 4.1, 4.2, 4.3, 4.4, and 4.5. The flow diagrams use descriptive text and make reference to PMM FORTRAN subroutine names, which are described in detail in sections 4.1, 4.2, 4.3, and 4.4. Additionally the REFINE calls the ETHANOL subroutine, which provides the PMM with supply curves for ethanol. The ETHANOL subroutine is documented in Appendix I.

The REFINE subroutine initializes variables and reads fixed data during the first year and first iteration of any NEMS run (Figure 4.1). The subroutine then follows one of five branches depending on the type of NEMS iteration as follows:

- **(Setup)** If the history switch is on and it's the first year and first iteration, historical values are read and the LP matrix is loaded into memory to await processing in the PMM base year.

- **(History Year)** If the history switch is on and it is a historical year after the first year and first iteration, then the PMM performs no operations but simply returns to the NEMS system operations. No operations are performed because all historical data were retrieved and variables were updated on the first iteration of the first year.

[1]Mathematical Programming System format.

- **(Iterative NEMS Solution)** If the history switch is on, it is not a historical year, and it is not a reporting iteration; or if the history switch is off and it is not a reporting iteration; then the PMM LP matrix is updated with data from other NEMS models and static PMM input data variables and an optimal solution is calculated (Figures 4.1, 4.2, 4.3, and 4.5). Petroleum product prices and other PMM output data are retrieved from the LP optimal solutions and output variables are updated.

- **(Reporting/Capacity Expansion)** If it is a reporting iteration, the history switch is on, and it is not a historical year; or if it is a reporting iteration and the history switch is off; then several internal PMM analyst reports are updated. If it is also a capacity expansion year, then the PMM LP is solved using input data using expectation values for a future year to determine processing unit expansion for the intervening years (Figures 4.1, 4.4, and 4.5). The capacity expansion methodology is described in more detail below.

- **(Pre-Base Year Capacity Expansion)** If it is a reporting iteration, the Short Term Energy Outlook (STEO) benchmarking switch is on, and it is NEMS year six (1995); then the PMM LP is solved using input data using expectation values for a future year to determine processing unit expansion for the intervening years (Figures 4.1 and 4.4).

Capacity Expansion Methodology

PMM models capacity expansion for all the refinery processing units which include but are not limited to distillation capacity, vacuum distillation, hydrotreating, coking, fluid catalytic cracking, hydrocracking, alkylation, and ether manufacture. Capacity expansion occurs by processing unit, starting from base year capacities established by PAD District using historical data. Expansion is determined by the LP when the value received from the additional product sales exceeds the investment and operating costs of the new unit. The investment costs assume a 10-percent rate of return over a 15-year plant life. For more details on the calculation of the investment costs, refer to the Appendix F section on Refinery Investment Recovery Factors.

Expansion through 2002 is determined by adding to the existing capacities those units planned and under construction that are expected to begin operating during this time. Starting in year 2003, capacity expansion is done in 3-year increments. The PMM looks ahead in 2002 and determines the optimal capacities given the estimated demands and prices expected in the 2005 forecast year. The PMM then allows one-third of that capacity to be built in each of forecast years 2003, 2004, and 2005.[2] At the end of 2005 the cycle begins anew.

[2]The capacity expansion rates for select processing units were adjusted to be consistent with applicable regulatory requirements such as the Ultra-Low-Sulfur-Diesel Rule.

Figure 4.1 PMM Flow Diagram

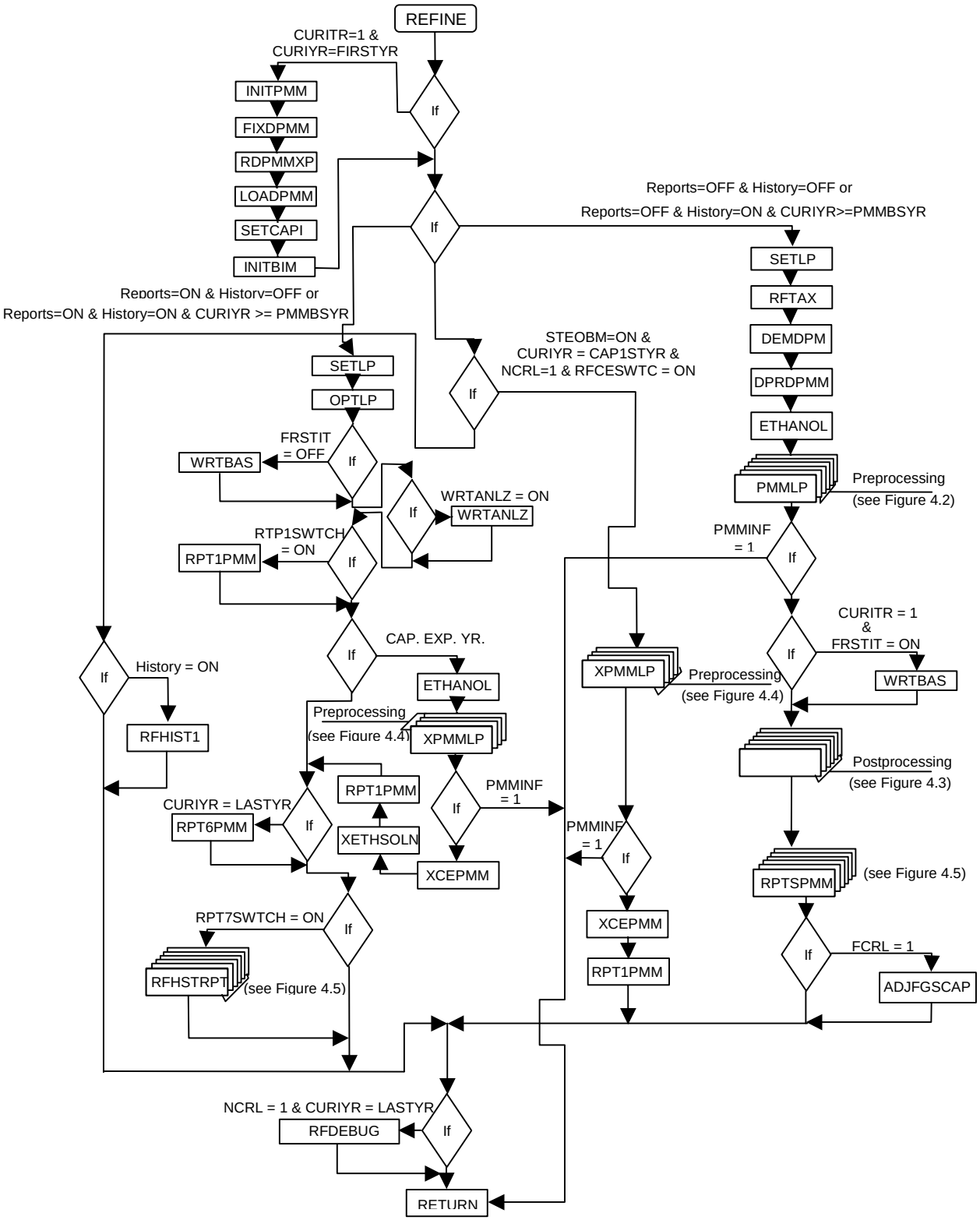


Figure 4.2 Matrix Preprocessing Subroutines (PMMLP)

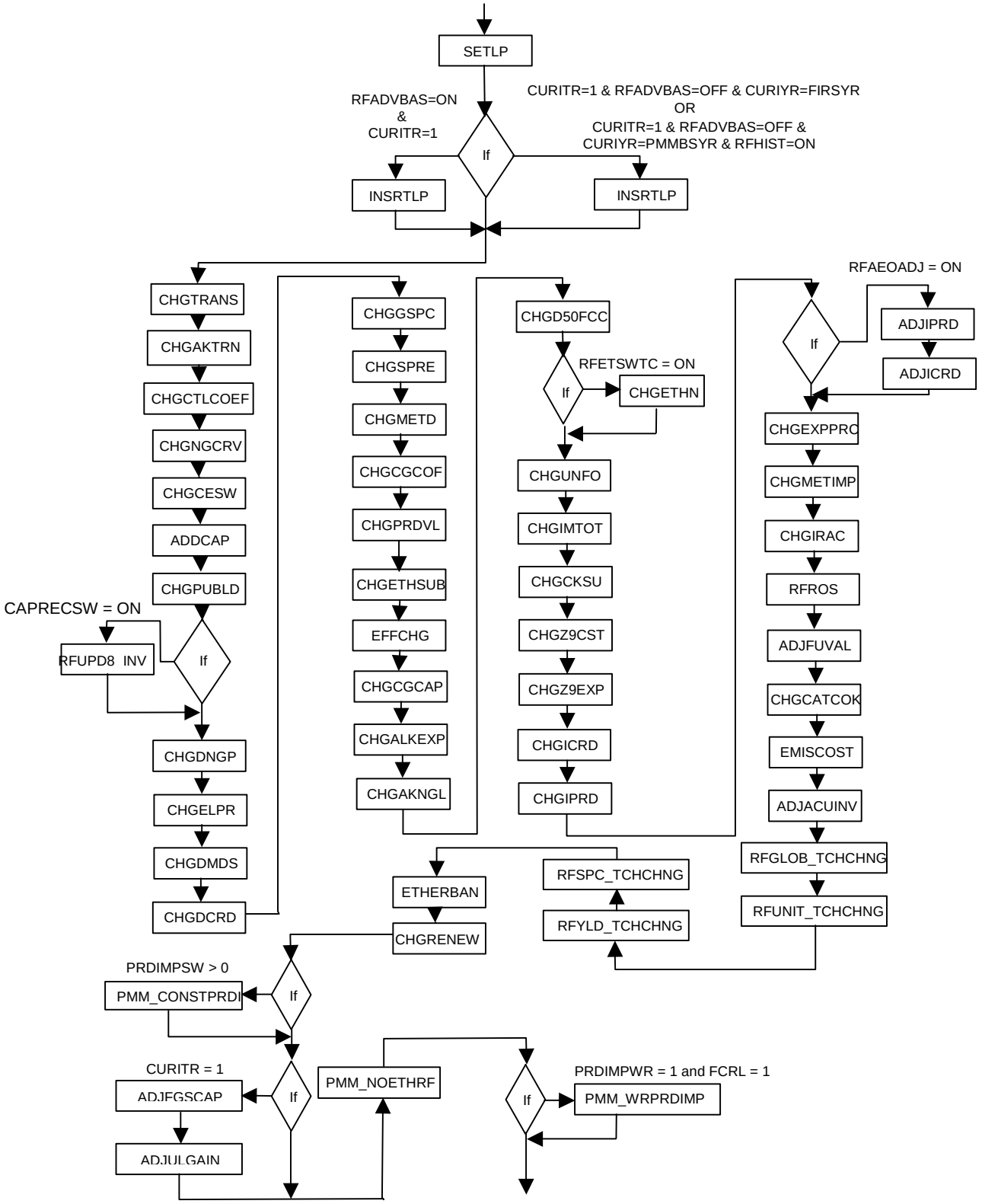


Figure 4.3 Matrix Postprocessing Subroutines

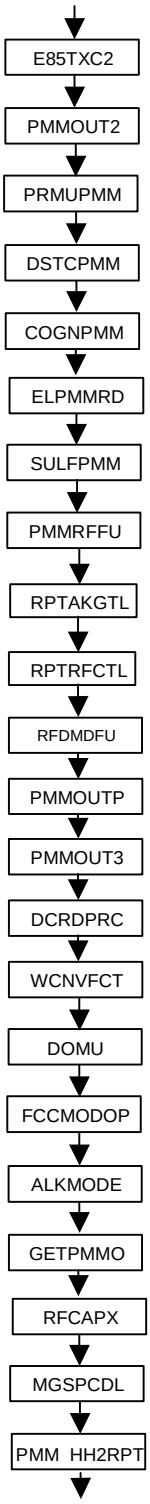


Figure 4.4 Capacity Expansion Subroutines (XPMMLP)

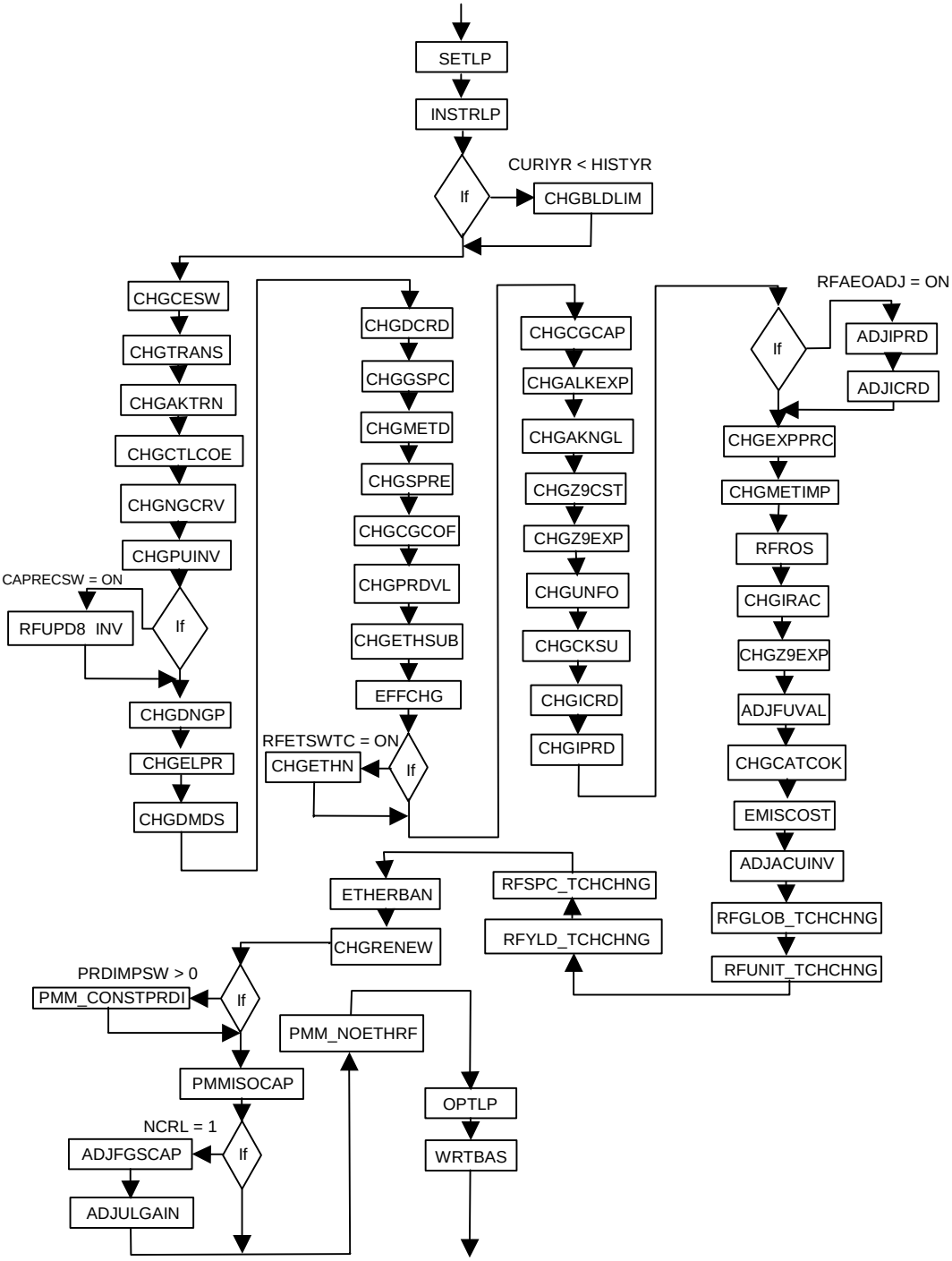
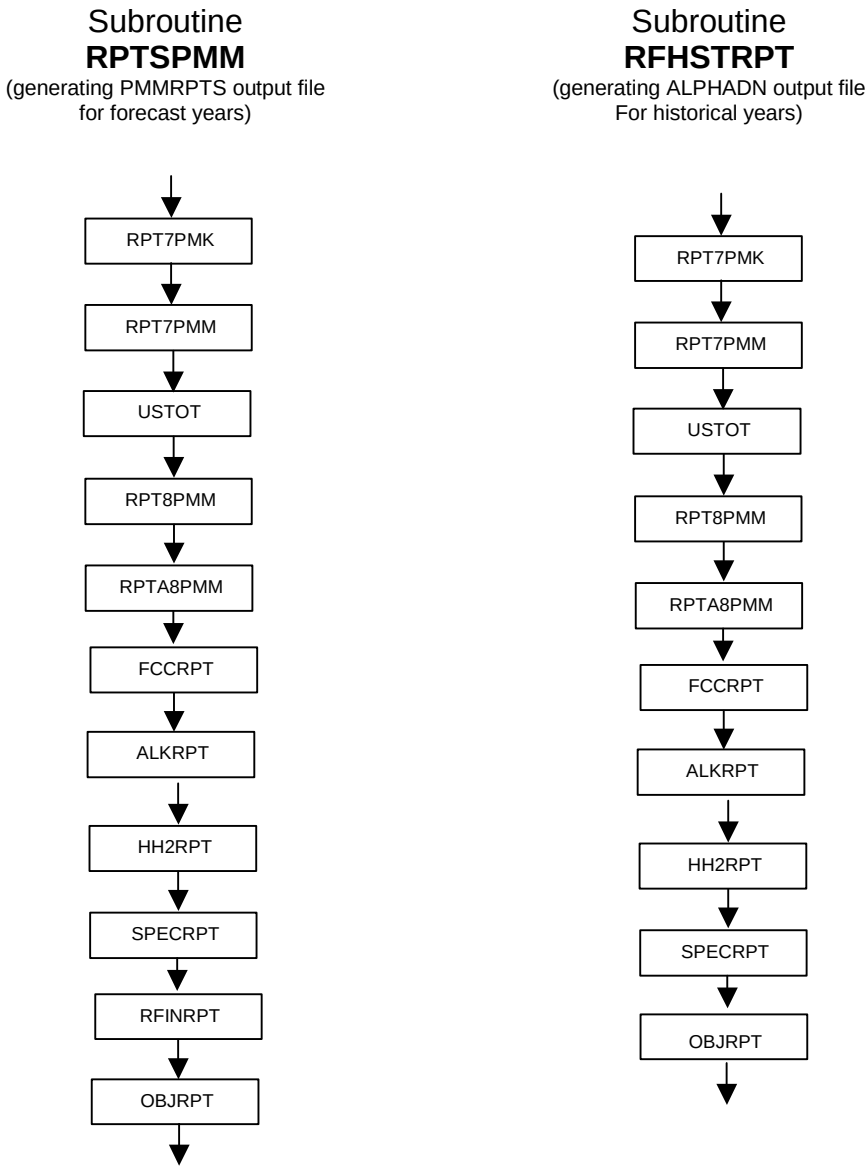


Figure 4.5 Report Subroutines



4.1 Main Subroutines

Section 4.1 describes the functions of the subroutines in Figure 4.1, the main controlling subroutines.

(REFINE) Main controlling subroutine for the PMM.

Purpose: REFINE is the driver subroutine for the PMM. It uses basic FORTRAN controlling structure, NEMS integrating model common variables, and PMM internal variables to set up and process the PMM LP and to update NEMS variables based on an optimal LP solution.

Equations: None.

(INITPMM) Initialize variables.

Purpose: Opens PMM iteration report file and PMM solution print file and initializes certain variables.

Equations:

$QBMET_{cd,yr} = 0.0$
$PUCUM_{pd,pu,yr} = 0.0$
$PUINV_{pd,pu,yr} = 0.0$
$RFQDINPOT_{pd,yr} = 0.0$
$PRDDMD_{pd,yr,pr} = 0.0$
$CRDOTHOT_{pd,yr} = 0.0$
$CRDUNACC_{pd,yr} = 0.0$
$CRDSTWDR_{pd,yr} = 0.0$
$CRDPRDSUP_{pd,yr} = 0.0$
$PRDSTKWDR_{pd,yr} = 0.0$
$BLDIMP_{pd,yr} = 0.0$
$QEXCRDIN_{pd,yr,pu} = 0.0$
$PUBASE_{pd,yr,pu} = 0.0$
$PUBASEUT_{pd,yr,pu} = 0.0$
$CFRGQ_{yr} = 5.253$ Conversion factor Reformulated Gasoline, MMBtu/Bbl
$CFTGQ_{yr} = 5.253$ Conversion factor Conventional Gasoline, MMBtu/Bbl
$PETTR_{yr,6} = 11.53$ E85 price for history and STEO years, $/MMBtu
$PETTR_{yr,7} = 11.99$
$PETTR_{yr,8} = 12.12$
$PETTR_{yr,9} = 10.58$
$PETTR_{yr,10} = 10.71$

$PETTR_{yr,11}$ = 12.56
$PETTR_{yr,12}$ = 12.56
$PETTR_{yr,13}$ = 12.56
$PMETR_{yr,6}$ = 9.23 M85 price for history and STEO years, $/MMBtu
$PMETR_{yr,7}$ = 8.33
$PMETR_{yr,8}$ = 9.87
$PMETR_{yr,9}$ = 6.63
$PMETR_{yr,10}$ = 7.71
$PMETR_{yr,11}$ = 9.99
$PMETR_{yr,12}$ = 9.99
$PMETR_{yr,13}$ = 9.99
$PMETR_{yr,14}$ = 9.99

where:

pd = 1,2,3: refinery regions (PAD Districts I, II-III-IV, V)
cd = 1,2,...11: Census Division, CA, and totals
pu = 1,2,...72: Processing unit identifier index
yr = 1,2,...36: NEMS year index
pr = 1,2,...24: PMM product identifier index

(FIXDPMM) Read fixed inputs.

Purpose: FIXDPMM reads in and initializes internal data required for processing the PMM.

Equations: None.

Input File:		
	MU1PRDS	Tax input data
	MU2PRDS	Sectoral end-use markups
	QDCRDCF	Fixed Data input file; also allowing definition of scenarios for special studies
	RFINVEST	Investment Data input file

(RFREAD_TCHCHNG) Read inputs.

Purpose: RFREAD_TCHCHNG reads information used to represent technology improvements.

Equations: None.

Input File:		
	QDCRDCF	Fixed Data input file; also allows definition of scenarios

(RFREAD_BLDSPLT) Read inputs.

Purpose: RFREAD_BLDSPLT reads information to define capacity expansion ratios for specified units during a 3-year expansion cycle.

Equations: None.

Input File: QDCRDCF Fixed Data input file; also allows definition of scenarios

(PMMREAD_PRDIMP) Read inputs.

Purpose: PMMREAD_PRDIMP reads product import results from a previous run-- only if the scenario prescribes constant product imports.

Equations: None.

Input File: RFPRDIMP Fixed Data input file containing product imports, by year, region

(RDPMMXP) Reads in the PMM specific expectation values from an input file.

Purpose: The RDPMMXP subroutine reads the SPRFLRT input file (which is generated from a previous PMM capacity expansion cycle) and updates PMM specific expectation values. These values are used for refinery capacity planning.

Equations: None.

Input file: SPRFLRT PMM specific expectations input file.

(LOADPMM) Sets up the PMM LP for processing by the OML.

Purpose: This subroutine defines the Optimization Modeling Library (OML) model space for PMM LP matrix. Loads the PMM LP matrix into memory and initializes OML model specific variables.

Equations: None.

(DEFLP) Defines and OML LP matrix model space and initializes common control variables for a given model.

Purpose: Defines and OML LP matrix model space and initializes common control variables for a given model using the OML function WFDEF.

Equations: None.

Data Passed: MODEL, model name, SIZE, model size

(MPSINLP) Converts a model from the MPS format file and stores it in the model database.

Purpose: Converts a model from and MPS format file to an OML model format and stores it in the model database using the OML function WFMSPIN.

Equations: None.

(LOADLP) Loads the LP model from the database into memory.

Purpose: Loads the LP model from the OML model database into memory and prepares it for optimization using the OML function WFLOAD.

Equations: None.

(SETCAPI) Sets initial refinery unit capacity.

Purpose: SETCAPI retrieves the existing capacity value and puts it into a variable PMMCAPI. Lower bound set for ACU based on historical utilization. Also, processing units not allowed to build (as defined in the qdcrdcf.txt file) are initialized with upper bound on builds equal to zero.

Equations: None.

(INITBIM) Initialize the supply curve for biomass diesel.

Purpose: INITBIM initializes the biomass diesel supply to zero.

Equations: None.

(RFHIST1) Read in history data for 1990 through 2001.

Purpose: RFHIST1 reads in history data from an external file and updates PMM output data for history years 1990 to 2001 and STEO year 2002 and 2003.

Equations: None.

Input File: ELCGPUR PMM historical data input file

(PMM_NEXTDATA) Advances file pointer one record.

Purpose: This subroutine is used to automate reading the historical data file. It advances the file pointer one record until the historical data record is located.

Equations: None.

(RFTAX) Aggregates State and Federal petroleum product taxes.

Purpose: RFTAX aggregates the State's and Federal petroleum taxes.

Equations: Total petroleum product tax are set at the State tax plus the nominal dollars federal tax.

(DEMDPMM) Convert system demands.

Purpose: Convert NEMS demands from trillion Btu to thousands of barrels per day for input into the refinery LP. Disaggregates gasoline and distillate fuel into types. Calculates U.S. total petroleum product demand by sectors.

Equations: The conversion from trillion Btu to Mbbl/d is as follows:

$$PRDDMD_{cd,yr,pd} = (((Q(PR)AS_{cd,yr}-Q(FPR)RF_{cd,yr})/CF(PR)Q_{yr})/365)*1000$$

The conversion from trillion Btu to MMbbl/d is captured in the following variables:

$$RFQ(PR)_{cd} = (Q(PR)AS_{cd,yr}/CF(PR)Q_{yr}) / 365$$

The motor gasoline share of M85 and E85 transportation fuels are also added to the total motor gasoline demands such that:

$$RFQMG_{cd} = ((QMGAS_{cd}+QMETR_{cd}*0.15+QETTR_{cd}*0.15)/CFMGQ/ 365$$

where;

PRDDMD = product demand by Census division (Mbbl/d)
RFQ(PR) = product demand by Census division (MMbbl/d)
Q(PR)AS = product demand in all sectors

Q(FPR)RF = product consumed for refinery fuel (applies only to products LG, RL, RH, DS, PC, SG, and OT)
CF(PR)Q = conversion factor (MMBtu/bbl)
(PR) = product types
(FPR) = refinery fuel products identifier
cd = Census Divisions 1 through 9
pd = refinery regions 1,2,3 (PAD Districts I, II-III-IV, V)
yr = forecast year
0.15 = Motor gasoline share of the alternate transportation fuel
365 = days per year
1000 = millions to thousands

Refinery fuel consumption, Q(FPR)RF, is subtracted from the product demands since the refinery model is designed to meet demand for saleable products. The variables RFQ(PR), Q(PR)AS, and Q(FPR)RF, and CF(PR)Q are defined explicitly in Appendix A 1.2, Refine Module Variables.

Four types of gasoline are derived from total gasoline demand by applying market share estimates:

$$PRDDMD_{cd,yr,t+1} = ((QMGAS_{cd,yr}/CF(t)Q_{yr}) / 365 * 1000) * MGSHR_{yr,t,cd}$$

where;

PRDDMD = product demand by Census Division
t = motor gasoline product designator index (1,2,3,4)
MGSHR = motor gasoline market shares

Refer to Appendix F (F.8) for more information on the derivation of the gasoline market shares, MGSHR.

Low-sulfur (500 ppm) and ultra-low-sulfur (15 ppm) diesel fuels combined is determined as a share of transportation and industrial distillate demand (Refer to Appendix F, Estimation of Low-Sulfur Diesel Market Shares, for more details):

$$PRDDMD_{cd,yr,13} = ((DSLSPLT*QDSTR(I,J)) + (DSLIND*QDSIN(I,J))) /CFDSQ/365*1000$$

where:

13 = product index for low-sulfur diesel (DSL)
DSLSPLT = 1.00

DSLIND = 0.00
QDSTR = quantity of transportation distillate
QDSIN = quantity of industrial distillate
CFDSQ = conversion factor for DSL (MMBTU/bbl)
365 = days per year
1000 = millions to thousands

Ethanol and methanol consumed in the transportation sector are assumed to be blends of 85 percent alcohol and 15 percent gasoline. Therefore, the demand for transportation ethanol and methanol in the PMM are 85 percent of total transportation alcohol demand, and 15 percent of the total transportation alcohol demand is added to gasoline demand.

Finally, U.S. totals are calculated:

$$PRDDMD_{11,yr,pr} = \sum PRDDMD_{cd,yr,pr}$$

where;

11 = total U.S. demand index
pr = product index 1 through 24
cd = Census divisions 1 through 9
yr = NEMS year index 1 through 36

(DPRDPMM) Update domestic crude wellhead price and gas plant fuel consumption.

Purpose: Update domestic crude wellhead price and gas plant fuel consumption for the Oil and Gas Supply Model and Natural Gas Transmission and Distribution Model.

Equations: None.

(ETHANOL) Calculates the ethanol supply step functions.

Purpose: Calculates the ethanol supply step functions for both corn and biomass based ethanol. Ethanol is used in the manufacture of gasoline, E85, and ETBE.

Equations: See Appendix I for a more detailed description of the biofuels supply submodule.

(PMMLP) Solve PMM LP.

Purpose: PMMLP calls many subroutines that perform updates to the LP bounds, RHS, and input costs and optimizes the matrix.

Equations: Refer to Appendix B.

(WRTBAS) Write advance basis.

Purpose: WRTBAS writes the basis for the LP optimal solution to an external file for any given NEMS year by calling the PUNCHLP subroutine.

Equations: None.
Output File: BASPMM1 and BAXPMM1 (for capacity expansion) PMM basis output file

(SETLP) Activates a specified OML model memory space for processing.

Purpose: Sets a given OML model space to be active using the WFSET function, such that any OML routines called will be applied to the given model.

Equations: None.

(OPTLP) Optimizes the model.

Purpose: Optimizes the model using the OML function WFOPT.

Equations: None.

(WRTANLZ) Writes an ANALYZE packed LP matrix and solution file.

Purpose: WRTANLZ writes an ANALYZE packed LP matrix and solution file the LP matrix and solution specified in memory using the GOMOT subroutine.

Equations: None.

Output File: PACKPMM PMM ANALYZE output file

(XCEPMM) Retrieve and calculate processing unit capacity expansion investment bounds.

Purpose: XCEPMM retrieves the expected processing investment activity level by using the SCOLLP subroutine and calculates the processing unit build and investment bounds.

Equations: Processing unit cumulative builds and investment bounds are calculated such that:

$PUINV_{pd,yr+1,pu} = BLD_{pd,pu,yr+3} / 3$
$PUINV_{pd,yr+2,pu} = BLD_{pd,pu,yr+3} / 3$
$PUINV_{pd,yr+3,pu} = BLD_{pd,pu,yr+3} / 3$

where:

PUINV = processing unit investment bound, Mbbl/cd
$BLD_{pd,pu,yr+3}$ = processing unit expansion as determined in expansion year yr
pu = processing unit index, 1 through 82
pd = refinery regions 1,2,3 (PAD Districts I, II-III-IV, V)
yr = NEMS index years 13,16,19,22,25,28,31,34

The decision to allow one-third of the expansion to come on line in each of the expansion years was made because expansions in individual refineries would most likely be spread out evenly in time as the PMM assumes an aggregated refinery for each PADD. The capacity expansion rates for select processing units can be adjusted (input file, qdcrdcf.txt) so that they are consistent with the capacities needed to meet certain regulatory requirements such as the Ultra-Low-Sulfur-Diesel Rule. Capacity expansion for the crude distillation unit has been limited to 2,600 MBCD for each refining region in the high macroeconomic and low world oil price cases and 2,250 MBCD for each region for all other cases.

Processing unit cumulative builds, PUCUM is:

$PUCUM_{pd,pu,yr} = 0$; when yr = 10
$PUCUM_{pd,pu,yr+2} = PUCUM_{pd,pu,yr+1} + PUINV_{pd,pu,yr+1}$
$PUCUM_{pd,pu,yr+3} = PUCUM_{pd,pu,yr+2} + PUINV_{pd,pu,yr+2}$
$PUCUM_{pd,pu,yr+4} = PUCUM_{pd,pu,yr+3} + PUINV_{pd,pu,yr+3}$

pu = processing unit index, 1 through 82
pd = refinery regions 1,2,3 (PAD Districts 1, 2-3-4, 5)
yr = NEMS index years 13,16,19,22,25,28,31,34

(RPT1PMM) Write report 1, LP solution.

Purpose: RPT1PMM writes the LP solution to an external file.

Equations: None.

Output File: PMMPRNT PMM solution output file

(XETHSOLN) Update Common Block Variables for ethanol production

Purpose: Updates the PMM and NEMS system common block values of ethanol production volumes by NEMS by type of feedstock. This is done at each iteration for every projection year.

Equations: Column activity solution values of the PMM LP, representing total ethanol production are read and corresponding common block variables are updated.

(RPT6PMM) Write report 6, OML formatted tables, supply curves and demands.

Purpose: RPT6PMM writes OML tables used for stand-alone PMM matrix generation.

Equations: None.

Output File: IMPCURV OML data table output file

(RFHSTRPT) Write ALPHADN reports for history data.

Purpose: This subroutine calls the report writer subroutines (including RPT7PMK, RPT7PMM, USTOT, RPT8PMM, RPTA8PMM, FCCRPT, ALKRPT, HH2RPT, SPECRPT, OBJRPT) and overwrites to an external file (PMM analyst reports) each NEMS iteration and at the end of a NEMS run.

Equations: None.

Output File: PMMRPTS PMM reports output file

(RPTSPMM) Write additional reports, PMM forecast reports.

Purpose: This subroutine calls the report writer subroutines (including RPT7PMK, RPT7PMM, USTOT, RPT8PMM, RPTA8PMM, FCCRPT, ALKRPT, HH2RPT, SPECRPT, OBJRPT) and overwrites to an external file (PMM analyst reports) each NEMS iteration and at the end of a NEMS run.

Equations: None.

Output File: PMMRPTS PMM reports output file

(ADJFGSCAP) Updates the upper limit on the FGS unit.

Purpose: ADJFGSCAP increases the upper limit on the FGS processing unit each year based on its utilization in the previous years (beginning after 2006).

Equations: $FGS\_UL_{pd,yr} = FGS\_SOL_{pd} * (1. + FGS\_PCT_{pd})$

where:
pd = refinery regions 1,2,3 (PAD Districts I, II-IV, V)
yr = forecast year

(RFDEBUG) Write debug information concerning GTL results.

Purpose: RFDEBUG writes GTL information (e.g., AK natural gas consumption for GTL, GTL production, and GTL exports) to a debug output file

Equations: None.

Output File: PMMDBG.txt output file

(RPT7PMM) Write report 7 (US end-use prices without Carbon tax), PMM forecast reports.

Purpose: RPT7PMM extracts solution values from the LP using the SCOLLP and SROWLP subroutines and overwrites to an external file (PMM analyst reports) at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix, reformatted and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(RPT7PMK) Write report 7 (US end-use prices with Carbon tax), PMM forecast reports.

Purpose: RPT7PMK extracts solution values from the LP using the SCOLLP and SROWLP subroutines and overwrites to an external file (PMM analyst reports) at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix, reformatted and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(USTOT) Calculates totals by PAD District, Census Division, and U.S. for RPT7PMM, RPT8PMM, and RPTA8PMM.

Purpose: Totals various PMM output data.

Equations: Performs units conversions on some of the totals.

(RPT8PMM) Write report 8, continuation of report 7.

Purpose: RPT8PMM pulls solution values from the LP using the SCOLLP and SROWLP subroutines and writes to an external file PMM analyst reports at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix, reformatted, and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(RPTA8PMM) Write report A8, continuation of report 8.

Purpose: RPTA8PMM pulls solution values from the LP using the SCOLLP and SROWLP subroutines and writes to an external file PMM analyst reports at the end of a NEMS run.

Equations: Solution values are extracted from solution matrix, reformatted, and converted to the proper units.

Output File: PMMRPTS PMM reports output file

(FCCRPT) Reports the fluid catalytic cracker's level of operations.

Purpose: This subroutine reports the levels of operations for the modes of operation of the fluidized catalytic cracker.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(ALKRPT) Prints the alkylation report to the PMM forecast reports.

Purpose: Solution values extracted using the subroutine ALKMODE are reformatted and printed to an output file.

Output File: PMMRPTS PMM reports output file.

(HH2RPT) Prints the hydrogen production and consumption report to the PMM forecast reports.

Purpose: Solution values extracted using the subroutine PMM_HH2RPT are reformatted and printed as Table 48 to an output file.

Output File: PMMRPTS PMM reports output file.

(RFINRPT) Prints the refinery financial information report to the PMM forecast reports.

Purpose: Refinery financial information (including revenues, raw materials, energy costs, petroleum products, operating expenses, blending components, and investment costs) are reformatted and printed as Table 50 to an output file.

Output File: PMMRPTS PMM reports output file.

(SPECRPT) Prints the motor gasoline specifications report.

Purpose: SPECRPT print the motor gasoline specification report to the detailed PMM reports.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(OBJRPT) Prints the objective function report.

Purpose: OBJRPT print the objective function of the PMM for the NEMS forecast to the PMM detailed reports output file.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(PMMRPTHD) Prints the detailed PMM reports header.

Purpose: PMMRPTHD print the NEMS scenario name, date key, and reporting years as a header to each reporting the detailed PMM reports.

Equations: None.

Output File: PMMRPTS PMM reports output file.

(PMMRPTRW) Rewinds the record pointer during the PMM iterations report.

Purpose: PMMRPTRW rewinds the record pointer for the PMM iterations reports such that only each years final iteration reports are retained.

Equations: None.

Output File: ALPHADN PMM reports output file.

4.2 Matrix Preprocessing Subroutines

Section 4.2 describes the function of the subroutines in Figure 4.2, preprocessing of the PMM matrix.

(INSRTLP) Loads an advance basis into the LP model.

Purpose: Loads a standard format basis from a file into the LP model using the OML function WFINSRT.

Equations: None.

(CHGTRANS) Updates the transportation costs of crude and product.

Purpose: Update the crude and product transportation cost within the United States.

Equations: Cost for moving crude and products from the supply regions to the demand regions are updated to reflect changes in the world oil price, WOP. A factor called price delta is calculated as the change between the current year WOP and the previous year's WOP. The price delta is used to adjust the transportation cost for domestic crude and product shipments as the fractional change in price.

(CHGAKTRN) Updates the transportation costs of Alaska crude and GTLs from Alaska N. Slope to Valdez.

Purpose: CHGAKTRN updates the transportation costs for Alaska crude and GTLs from Alaska N. Slope to Valdez. Also defines the natural gas supply curve and maximum supply, the remaining capacity for GTL, and GTL subsidies that apply.

Equations: Transportation costs are based on fixed costs for the TransAlaska Pipeline System (TAPS), variables charge, estimated flows, and GTL subsidies. The annual NG supply curve is represented as a cumulative supply curve, and a cumulative maximum is defined exogenously. The GTL subsidy is based on the Alaska oil price and economics associated with TAPS.

(CHGCTLCOEF) Updates the coefficients on the CTL input components

Purpose: CHGCTLCOEF updates the coal supply curve used to generate liquids and cogeneration from CTL processing units. Cogeneration credits and CTL transportation costs are defined. Also, regional coal conversion ratios are set.

Equations: The coal supply curve (including transportation costs) is based on quantities, prices, and elasticities provided by the coal supply module. Cogeneration credits are a function of the electricity price to the industrial sector. Finally, regional coal conversion ratios are based on the higher heating values of the respective coals, and an average conversion rate.

(CHGNGCRV) Updates the natural gas supply curve for refinery fuel use.

Purpose: Updates the bounds on the first point of the eight-step natural gas supply curve using the CBNDLP subroutine.

Equations: The lower bound on step one of the supply curve is set at 50 percent of the sum of the upper bounds on the last four steps of the supply curve. The upper bound on step one of the supply curve is set at 80 percent of the sum of the upper bounds on the last four steps of the supply curve during any first iteration of a NEMS year or the capacity planning iteration. During any other NEMS iteration the upper bound on the first step of the supply curve is set at the difference between the sum of the upper bounds of the last four steps on the supply curve and the difference between the sum of the upper bounds on the first four steps of the supply curve and the sum of activity levels on all steps of the supply curve from the previous NEMS iteration solution. If the upper bound on the first step of the supply curve, just described falls below the lower bound on the first step of the curve, then the upper bound is set at value 1 percent above the lower bound on the first step of the curve. This methodology effectively re-centers the natural gas supply step function during each NEMS iteration.

(CHGCESW) Update Capacity Expansion Switch.

Purpose: CHGCESW changes the LP constraint that allows investment in processing units capacities to compete with imported products by using the CRHSLP subroutine.

Equations: None.

(ADDCAP) Update Capacity.

Purpose: ADDCAP changes the capacity expansion investment and build bounds using the CBNDLP subroutine with values obtained from the XCEPMM subroutine.

Equations: None.

(CHGPUBLD) Updates the bounds on the processing unit investment columns.

Purpose: If the STEO benchmarking switch is off, this subroutine sets the upper and lower bounds for the processing units investment columns to zero during initial model startup. During

the first year that the PMM model is run, the CHGPUBLD subroutine insures that the model will not build any additional capacity. Capacity additions are handled by the capacity expansion portion of the PMM.

Equations: None.

(RFUPD8_INV) Update Investment Coefficients for Capacity Build and Investment Variables

Purpose: This subroutine generates new capital recovery, fixed operating cost, and investment information (using subroutine RFINVST) and updates the capacity build and investment coefficients in the LP objective function row and other constraint rows (using subroutine CVALLP).

Equations: The subroutine RFINVST uses "Refinery Investment Recovery Thresholds" methodology defined in Appendix F (F.1) to generate the capital recovery, fixed operating cost, and total investment information. The first two components are then added and multiplied by an investment location factor and an environmental factor (and by -1). Next, in order to maintain an accounting of previous investment levels, this value is averaged using the function ADJBLD_COEF. The objective function row coefficients identified above are updated using these results. However, if the model is being set up for capacity expansion, then the original value, not the averaged value, is used to update the investment coefficient only. The original fixed cost and investment information are also used to update other row constraint coefficients that intersect the investment variable.

(CHGDNGP) Update Natural Gas Production and Prices.

Purpose: Natural gas production and prices come from the Natural Gas Transmission and Distribution Model and are inputs to the gas plant portion of the model. This subroutine updates these LP inputs using the CBNDLP and CVALLP subroutines. During the capacity expansion iteration the CHGDNGP subroutine uses the expected natural gas production and prices as inputs into the LP model.

Equations: The industrial interruptible price of natural gas is used for the prices of gas to refineries in each PAD District, translated into refinery regions (1=PADD I, 2=PADDs II,III,IV, 3=PADD V). These prices are converted to $/MCF. During the capacity expansion iteration the expected industrial interruptible price of natural gas and expected domestic production of natural gas is used as inputs into the LP matrix.

(CHGELPR) Update electricity costs.

Purpose: CHGELPR updates the cost of electricity in each of the refinery regions using industrial price of electricity using the CVALLP subroutine. During the capacity planning iteration the CHGELPR subroutine uses the expected cost of electricity in each of the refinery regions.

Equations: Industry price of electricity is mapped from Census division to refining region (1=PADD I, 2=PADDs II,III,IV, 3=PADD V), and units are converted to $/kWh.

(CHGDMDS) Update product demands for the LP.

Purpose: CHGDMDS sets the upper and lower bounds for product demands. For most products, the upper and lower bounds are equal. The bounds are set at the level of demand for each product in each Census Division. During the capacity expansion iteration the CHGDMDS updates bounds using the expected demands variables. CHGDMDS can also used to set bounds for product(s) subject to current laws and regulation, such as MTBE ban in California starting 2004.

Equations: None.

(CHGDCRD) Update domestic crude production.

Purpose: CHGDCRD updates the LP domestic crude production variables using the CBNDLP subroutines. During the capacity planning iteration the CHGDCRD subroutine updates the domestic crude production bounds using the expected crude production variables.

Equations: U.S. crude production and units are converted to Mbbl/cd.

(CHGGSPC) Updates the motor gasoline specifications.

Purpose: CHGGSPC updates motor gasoline specifications using the CVALLP subroutine..

Equations: Sub-specification blends of reformulated and high-oxygenated-conventional gasoline are calculated for ethanol blends for these fuels using the percent ethanol blended.

(CHGSPRE) Change Strategic Petroleum Reserve (SPR) and Crude Oil Exports for the LP.

Purpose: Sets the upper and lower bounds for SPR additions and non-Alaska crude oil exports. For both items, the upper and lower bounds are equal and are set using the CBNDLP subroutine. The bounds on SPR additions are set as exogenous inputs to the program, while non-Alaska crude oil exports are a function of total exports.

Equations: Total exports are calculated using a regression equation, with non-Alaska exports set at 40 percent of the total.

(CHGMETD) Change methanol demand for the LP.

Purpose: Sets the upper and lower bounds for methanol demand. The upper and lower bounds are equal. During the capacity expansion iteration the expected methanol demand is used to update the bounds.

Equations: None.

(CHGCGCOF) Updates the cogeneration sales to grid coefficients for the cogeneration processing unit.

Purpose: Updates the cogeneration sales to grid coefficients using the CVALLP subroutine for the cogeneration processing unit.

Equation: $COEF_{pd,yr} = CNST_{pd} * PELAS_{cd,yr} * CFELBK$

where:
COEF = sales to grid coefficient
CNST = Percent sales to grid for each refinery region *pd* based on historical data (see sect. F.15).
PELAS = Prices of electricity to all sectors
CFELBK = conversion factor, $3412 * 10^{-6}$ MMBTU/KWH
pd = refinery regions 1,2,3 (PAD Districts I, II-III-IV, V)
cd = Census Division index
yr = year index

(CHGPRDVL) Update the objective row of the product demands column.

Purpose: This subroutine updates the objective row value for the product demand columns.

Equations: The coefficients for the product demand columns in the objective row are updated as a function of corresponding end-use prices resulting from the previous NEMS iteration. For coke, the update is a function of two times the world oil price.

(CHGETHSUB) Updates LP coefficient that handles the ethanol subsidy.

Purpose: This subroutine updates the LP coefficient for the ethanol subsidy for ethanol (from corn or cellulose) blended into motor gasoline. Only the ethanol portion of E85 receives the ethanol subsidy.

Equations: The ethanol subsidy is set at $23.68 /Bbl in 2000 (nominal dollars), $22.26 /Bbl in 2001 and 2002 (nominal dollars), $21.84 /Bbl in 2003 and 2004 (nominal dollars), and $21.42 /Bbl after 2005 (nominal dollars). All these prices are converted to 1987 dollars (using the macroeconomic GDP deflator) before being put into the matrix; therefore, the model sees the ethanol subsidy declining in real terms over the entire forecast.

(EFFCHG) Updates the efficiencies for steam, electricity, and natural gas.

Purpose: This subroutine updates the efficiency coefficients for steam, electricity, and natural gas in the NEMS hi-tech scenario only (using subroutine CVALLP).

Equations: Sets percentage efficiency improvement based on estimated total carbon emissions.

(CHGCGCAP) Updates the refinery cogeneration capacities.

Purpose: This subroutine updates the base refinery cogeneration capacities with the planned additions.

Equations: No planned additions for *AEO2003* due to unavailable cogeneration data.

(CHGALKEXP) Updates the LP Alaskan export crude supply curve.

Purpose: The LP Alaskan export crude supply curve is updated.

Equations: The price steps on the supply curve are set as a function of world oil prices such that the price is 83.2 percent of the world oil price. Total Alaskan exports are set at 60 percent of total crude exports, with each step of the supply curve (six steps total) representing one-sixth of this volume. These prices and volumes were set based on analyst judgment.

(CHGAKNGL) Updates Alaskan natural gas liquids production.

Purpose: This subroutine updates the LP Alaskan natural gas liquid bounds using the OGSM variable OGNGLAK.

Equations: None

(CHGD50FCC) Updates the minimum flow constraint on the D50 (winter) mode in the FCC.

Purpose: This subroutine updates the minimum percentage flow constraint on the D50 mode in the fluid catalytic cracker.

Equations: Set the constraint at a minimum of 7.5 percent of throughput. This value was made based on analyst judgment to meet the minimum winter mode of operation for the FCC unit.

(CHGETHN) Update ethanol supply curves in LP for both corn and cellulose sources.

Purpose: CHGETHN updates the LP ethanol supply curve representation with values obtained from the Renewable Fuels Model by using the CBNDLP and CVALLP subroutines. The ethanol supply curves are represented in the LP by a stepwise function comprised of five price/quantity pairs. See Appendix I for a more detailed description of the ethanol supply curves.

Equations: None.

(CHGUNFO) Update unfinished oil costs.

Purpose: CHGUNFO updates the cost of unfinished oils using the CVALLP subroutine.

Equations: Unfinished oils costs are set at a value based on typical refinery gate prices for the streams heavy gas oil medium sulfur (HGM), naphtha paraffinic (NPP), and atmospheric residual type B (ARB) as a function of crude oil price where:

$$ARB_{yr} = 0.90 * WOP_{yr}$$
$$NPP_{yr} = 1.14 * WOP_{yr}$$
$$HGM_{yr} = 1.05* WOP_{yr}$$

where

ARB = Atmospheric residual type B cost
NPP = Naphtha paraffinic cost
HGM = heavy gas oil medium sulfur cost
WOP = World oil price
yr = NEMS year, 1 through 36

(CHGIMTOT) Update total product imported constraint.

Purpose: CHGIMTOT updates the LP constraint for total maximum imported product using the CRHSLP subroutine.

Equations: Set to 9900 Mbbl/cd. This value is based on analyst judgment and is currently set high enough that the constraint is not expected to be reached.

(CHGCKSU) Update petroleum coke and sulfur costs.

Purpose: CHGCKSU updates the cost of petroleum coke, export and distress export petroleum coke costs, and the cost of sulfur using the CVALLP subroutine.

Equations: Petroleum coke costs are based on a 1991 price of $20/ton for low sulfur coke and $15/ton for high sulfur coke. These prices are converted to $/bbl and scaled by the 1991 world oil price (WOP). The results are values of 0.203 and 0.152 which are multiplied by the current year WOP to set the cost of coke. Costs to export coke are set at 3.15 times the high sulfur coke costs. Distress export of petroleum coke cost is set at 10.0 percent of the high sulfur coke costs. The average price of saleable sulfur is set to $24.47 /ton (in 87$).

(CHGZ9CST) Updates the distress product imports supply vectors input cost.

Purpose: Updates the distress product imports supply vectors input cost using the CVALLP subroutine.

Equations: The distress product imports input cost a set at five times the WOP.

(CHGZ9EXP) Updates the distress product exports supply vectors input cost.

Purpose: Updates the distress product exports supply vectors input cost using the CVALLP subroutine.

Equations: The distress product exports input cost a set at 10 percent of the WOP.

(CHGICRD) Update imported crude supply curve in the LP.

Purpose: CHGICRD updates the LP imported crude supply curves using values obtained from the International Model.

Equations: The International Model provides imported crude supply curves for each refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) and five crude types to the PMM. These imported crude supply curves represent three price-quantity relationships for each imported crude in each refining region. The second and third quantity steps for each supply curve are incremental supply volumes. The prices related to these incremental supply volumes are absolute prices. During the capacity expansion look-ahead iteration, CHGICRD updates imported supply curve bounds with the expected imported crude supply variables.

(ADJICRD) Adjust the international crude supply curves.

Purpose: This subroutine is used to make adjustments to the international crude supply curve prices.

Equations: For all crudes in each refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V), costs are adjusted as follows: the imported crude prices are adjusted to be directly related to the world oil price plus or minus a constant to account for crude quality and plus or minus the price differential between the supply step points on the original supply curves. These adjustments are estimated based on analyst judgment.

(CHGIPRD) Update imported product supply curves.

Purpose: CHGIPRD updates LP imported product supply curves using values passed from the International Model.

Equations: The International Model provides imported product supply curves to the PMM for each product and each refining region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V). These imported product supply curves represent price-quantity relationships for each imported product. The second and third quantity steps on the supply curves are incremental supply volumes. The prices related to these incremental supply volumes are absolute prices.

(ADJIPRD) Adjusts the international product supply curves.

Purpose: This subroutine makes adjustments to the international supply curve prices and/or volumes.

Equations: Adjusts the prices on the imported product supply curves to calibrate the petroleum product imports to values indicated in the *Petroleum Supply Annual 2001*. Adjustments are made to imports volumes and prices as follows. Note: volume adjustments for N6I and N6B occur only on the first step at a level one third that listed below.

Imported product	*Price Adjustment*	*Volume Adjustment*	*Region*
LPG	-1.00	0.0	1
TRG	-1.00	-15.0	1
RFG	-2.00	0.0	1
JTA	-2.35	30.0	1
N2H	-3.50	50.0	1
DSL	-1.50	10.0	1
N6I	0.00	10.0	1
N6B	-0.50	10.0	1
OTH	0.00	85.0	1
PCF	-0.50	20.0	1
MET	0.00	0.0	1
MTB	0.00	0.0	1
LPG	0.00	0.0	2
TRG	2.50	-50.0	2

RFG	0.50	0.0	2
JTA	0.00	0.0	2
N2H	2.00	0.0	2
DSL	0.00	0.0	2
N6I	-1.00	0.0	2
N6B	2.00	0.0	2
OTH	0.00	0.0	2
PCF	-1.00	0.0	2
MET	0.00	0.0	2
MTB	0.00	0.0	2
LPG	2.10	0.0	3
TRG	-1.00	0.0	3
RFG	1.50	0.0	3
JTA	-4.50	50.0	3
N2H	0.00	0.0	3
DSL	0.00	0.0	3
N6I	2.00	10.0	3
N6B	4.00	0.0	3
OTH	1.00	15.0	3
PCF	0.00	10.0	3
MET	0.00	0.0	3
MTB	0.00	0.0	3

(CHGEXPPRC) Update exported petroleum product prices and demand limits.

Purpose: This subroutine updates the objective row and upper and lower bounds for each exported petroleum product (except coke).

Equations: Set prices for exported products (excluding coke) to 90 percent of the imported product prices defined on the first step of the import supply curve. Also, set the upper and lower bounds on exported products (excluding coke) as a function of regional product demand, as follows:

$$LOWBND = 0.65 * EXPRDDMD_{xpr,pd} * EXPRAT * EXPMIN_{xpr,pd} / 100.$$
$$UPBND = 0.65 * EXPRDDMD_{xpr,pd} * EXPRAT * EXPMAX_{xpr,pd} / 100.$$

for PCF in CD = 9, UPBND = UPBND * 6.5
for OTH in CD = 9, UPBND = UPBND * 10.0
for years $\leq$ 1996, EXPRAT = 1
for years > 1996, EXPRAT = DUMTOT1 / DUMTOT2

Using regression analyses:

$$DUMTOT1 = [\ 7.942 - (0.4073 * (RFPQIPRDT_{6,yr,2} / RFQPRDT_{11,yr}\ )\ )\ * RFQPRDT_{11,yr}\ * 10^6$$
$$DUMTOT2 = [\ 7.942 - (0.4073 * (RFPQIPRDT_{6,y-1r,2} / RFQPRDT_{11,yr-1}\ )\ )\ * RFQPRDT_{11,yr-1}\ * 10^6$$

where,

UPBND = upper bound on export product demands
LOWBND = lower bound on export product demands
EXPRDDMD = product demand accumulated into PAD Districts (I - V)
EXPMIN = factor to establish minimum product export range
EXPMAX = factor to establish maximum product export range
EXPRAT = ratio of estimated exports for year yr and yr-1
DUMTOT1 = estimated exports in year yr
DUMTOT2 = estimated exports in year yr-1
RFPQIPRDT = total imports for each product
RFQPRDT = total supply for each product
yr = year index
xpr = exported product index
pd = PAD District containing Census Division export region (I=>2, II=>3, III=>7, IV=>8, V=>9)

(CHGMETIMP) Updates the methanol imports supply function.

Purpose: This subroutine updates the methanol import supply curve costs and volumes.

Equations: The import supply curves are updated as a function of world oil price. These adjustment were made based on analyst judgment.

(CHGIRAC) Update average refinery acquisition cost parameters.

Purpose: CHGIRAC updates the average refinery acquisition cost constraints using the CVALLP subroutine.

Equations: Cost of crudes in each PAD District are updated and the minimum and maximum tolerance for the average acquisition cost are set to $0.50/bbl off the world oil price. This tolerance level was chosen based on analyst judgment.

(RFROS) Updates the renewable oxygenates constraint.

Purpose: RFROS updates the renewable oxygenates specification (ROS) constraints for motor gasoline using the CVALLP subroutine.

Equations: The motor gasoline minimum renewable oxygenates constraints are set at 0, 15, and 30 percent for the NEMS years 1994, 1995, 1996 and beyond respectively if the ROS switch is on. If the ROS switch is off the constraint is set to zero. For the *AEO2003* the ROS was off.

(ADJFUVAL) Adjust refinery fuel use coefficient on all refinery fuels.

Purpose: This subroutine is used to calibrate refinery fuel consumption with historical estimates. For the *AEO2003* this factor was 0.997.

Equations: None.

(CHGCATCOK) Updates catalytic coke coefficient.

Purpose: This subroutine updates the catalytic coke LP coefficient.

Equations: The coefficient is updated once at the beginning of the NEMS forecast and then remains constant throughout the NEMS forecast. The updated coefficient is set at 90 percent of the current value in the PMM database. This value is calibrated to reflect catalytic coke use as reported by the *Petroleum Supply Annual 2001*.

(EMISCOST) Updates the refinery emission cost vector.

Purpose: Update the input cost of the vector of the burning petroleum products in the refinery using the CVALLP subroutine.

Equations: Emission input costs are set at values determined by the Emission Policy Module.

(ADJACUINV) Updates the crude units investment costs

Purpose: This subroutine updates the atmospheric distillation unit investment costs.

Equations: The investment coefficient is updated once at the beginning of the NEMS forecast and then remains constant throughout the NEMS forecast.

(RFGLOB_TCHCHNG) Model technology changes as reflected by other variable cost (OVC) adjustment in all process units.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the OVC coefficient (by a user-specified amount) in the OVC constraint row for all process units (in the refinery, merchant, and gas plant).

Equations: If the global technology switch is on and the model year lies between the begining and end phase-in year, then the original OVC price coefficients for all processing units (except those also flagged for unit-specific technology improvement updates) included in the OVC constraint row are updated gradually during the phase-in years.

(RFUNIT_TCHCHNG) Model technology changes as reflected by other variable cost (OVC) adjustment only in specified process units.

Purpose: This subroutine approximates technology changes for specific processing units in the refining industry by adjusting the corresponding OVC coefficient in the OVC constraint row by a user-specified amount.

Equations: If the unit-specific technology switch is on and the model year lies between the beginning and end phase-in year, then the original OVC price coefficients for the specified unit(s) included in the OVC constraint row are updated gradually during the phase-in years.

(RFYLD_TCHCHNG) Model technology changes as reflected by process stream adjustment in a process unit.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the process stream yields coefficient (by a user-specified amount) of a user-defined process unit.

Equations: None.

(RFSPC_TCHCHNG) Model technology changes as reflected by process stream quality adjustment.

Purpose: This subroutine approximates technology changes in the refining industry by adjusting the process stream qualities (by a user-specified amount).

Equations: None.

(ETHERBAN) Updates motor gasoline blending constraints to eliminate ether blending in PADD V refiners.

Purpose: This subroutine updates PADD V gasoline blending constraints to eliminate ether blending into gasoline. This constraint takes effect in 2004 for California gasolines.

Equations: None.

(CHGRENEW) Updates the minimum renewables requirement in motor gasolines and on-road diesel

Purpose: This subroutine sets the RHS of the minimum renewables constraint and the biomas diesel production level.

Equations: The biomas diesel production is currently set exogenously. The mininum renewables requirement is a percent of the total (US) gasoline, diesel, and E85 demands.

(PMM_CONSTPRDI) Sets product imports to a constant level.

Purpose: This subroutine sets product imports to a constant level to allow for sensitivity runs without the impact of changing imports. Control switch: PRDIMPSW.

Equations: None.

(PMM_WRPRDIMP) Writes product import results to an output file.

Purpose: This subroutine writes product import results to an output file to be used as input for a run requiring constant product imports. Control switch: PRDIMPWR.

Output file: PMMDBG.txt

(PMM_NOETHRF) Prevents ethanol blending at the refinery.

Purpose: This subroutine prevents ethanol transfers to the refinery since ethanol is usually splash blended into gasoline at the end-use location.

Equations: None.

(ADUULGAIN) Sets a limit on GAIN increase from year to year.

Purpose: This subroutine defines a range of increase for GAIN each year.

Equations: The allowed rate of increase is defined exogenously, and applied cumulatively to a base level of gain in a specified forecast year.

RHSGAIN = -1000. * RFQPRCG(6,GYR)/10. * (1.+GAINRAT)**(K-GYR)

where
RFQPRCG = processing gain in year GYR
GAINRAT = rate of annual gain increase
GYR = year defined for base gain level
K = current year

4.3 Matrix Postprocessing Subroutines

Section 4.3 describes the function of the subroutines in figure 4.3, postprocessing of the PMM optimized matrix.

(E85TXC2) Calculate ethanol consumption and E85 Tax Subsidy Adjustment.

Purpose: This subroutine retrieves the quantity and cost of ethanol from corn and cellulose using the SCOLLP subroutine; and calculates ethanol consumption and the E85 tax subsidy adjustment for carbon mitigation.

Equations: Daily ethanol consumption from cellulose is converted into MMgal/yr. The E85 tax subsidy adjustment $/bbl is calculated as the difference between the cost of ethanol from cellulose and the cost of ethanol from corn.

(PMMOUT2) Update Common Block Variables

Purpose: Updates the PMM and NEMS system common block values of refinery production volumes by NEMS refinery product and by PAD District. Also updates the total U.S. production volumes by product. This is done at each iteration for every projection year.

Equations: Row activity solution values of the PMM LP, representing total refinery production by PAD District by refined product are sequentially read and corresponding common block variables are set to the matrix solution values or to sums of several values as appropriate. For instance, the common block variable to be updated may be LPG production for PAD District I. Then the solution activity for the LP row that controls LPG production volume in PAD District I is accessed from the LP solution area and the corresponding common block variable is set equal to that value.

(PRMUPMM) Add refinery fixed costs.

Purpose: Retrieves the marginal petroleum product prices from LP using the SROWLP subroutine and adds on the refinery fixed costs to determine the wholesale petroleum product costs. Demands are summed, and weighted average prices for each product by Census Division and total United States are calculated. The wholesale costs of residual fuel are determined using an econometric equation. Wholesale kerosene prices are set using the wholesale distillate prices.

Equations: Marginal prices for each gasoline are retrieved from the LP solution and refinery fixed costs are added to the marginal prices of each product:

$$P_{pr,cd,yr} = VALUE_{pr,cd} + RFPRDFX_{cd,yr,pr} * FXPCT$$

$$RFDL(pr)_{cd,yr} = VALUE_{pr,cd}$$

where:

RFDL(pr) = refinery marginal prices for each petroleum product pr (w/o markup)

P = refinery gate price of petroleum product pr [PMG(pr) and P(pr)] (w/ markup)

VALUE = the marginal value of petroleum product pr

RFPRDFX = the refinery fixed costs, including refinery operating costs, return on investment, and environmental control costs (see Appendix F).

FXPCT = percentage allocated of the fixed cost. Fixed costs are allocated only at 80, 80, 90, and 100 percent during the years 2003 to 2006 respectively. This lag in applying total fixed costs takes into account the expected time frame in refinery investment for environmental control costs.

pr = product

cd = Census Division

yr = NEMS index years

Wholesale prices of residual fuel are determined as a function of WOP and residual demand fraction, such that:

$$P_{pr,cd,yr} = 42 * (INTCP + SLP * (WOP_{yr}/42) + (CNSNT * ((QRL_{cd,yr} + QRH_{cd,yr})/QPRD_{cd,yr})))$$

where:

P = refinery gate price of low and high sulfur residual fuel [PRLEQ, PRHEQ, PRLUTEQ, PRHUTEQ]

INTCP = -0.057507 or -.117698 for low and high sulfur residual respectively

SLP = 0.979872 OR 1.001313 for low and high sulfur residual respectively

WOP = World oil price

CNSNT = 0.297792 or 0.42297 for low and high sulfur residual respectively

QRL = Demand for low sulfur residual fuel

QRH = Demand for high sulfur residual fuel

QPRD = Total petroleum product demand

pr = product (N6I, N6B, N67, N68)

cd = Census Division

42 = gallons per barrel

yr = NEMS index years

Demands for all four types of gasoline are summed by Census Division, and a national gasoline total is estimated by summing across Census Divisions:

$$MGDMDT_{cd} = \sum_{t=2,3,4,5} PRDDMD_{cd,yr,t}$$

$$MGDMDGT = \sum_{cd=1,9} MGDMDT_{cd}$$

where:
cd = Census Division 1 through 9
t = motor gasoline index type 2,3,4,5
yr = NEMS year index

National demand for each type of gasoline is estimated by:

$$MGDMD(t) = \sum_{cd=1,9} PRDDMD_{cd,yr,t}$$

where:
cd = Census Division 1 through 9
t = motor gasoline index type 2,3,4,5
yr = NEMS year index

A weighted average gasoline price (with and without markups) is calculated for each Census Division based on prices of the various types of gasoline.

$$PALMG_{cd,yr} = \sum_{pr=2,3,4,5} ((PMG(pr)_{yr,cd} * PRDDMD_{pr,yr,cd})/MGDMDT_{pr})$$

$$RFDLMG_{cd,yr} = \sum_{pr=2,3,4,5} ((RFDL(pr)_{yr,cd} * PRDDMD_{pr,yr,cd})/MGDMDT_{pr})$$

where:
PALMG = weighted average gasoline price, with markups
RFDLMG = weighted average gasoline price, without markups
PMG(pr) = refinery gate price of motor gasoline product pr
PRDDMD = product demand (motor gasoline only) by Census Division
MGDMDT = total motor gasoline demand by Census Division
RFDL(pr) = refinery marginal prices for motor gasoline (pr) product only
pr = motor gasoline index 2,3,4,5
cd = Census Division 1 through 9
yr = NEMS year index

National average prices for each product including individual types of gasoline are estimated by:

$$P_{pr,t,yr} = \sum_{cd=1,9} (P_{pr,cd,yr} * PRDDMD_{pr,yr,cd})/PRDDMD_{pr,yr,t}$$

$$RFDL(pr)_{t,yr} = \sum_{cd=1,9} (RFDL(pr)_{cd,yr} * PRDDMD_{pr,yr,cd})/PRDDMD_{pr,yr,t}$$

where:
P = refinery gate price of petroleum product pr [PMG(pr) and P(pr)] (w/ markup)
RFDL(pr) = refinery marginal prices for each petroleum product pr (w/o markup)
PRDDMD = product demand by Census Division
MGDMDT = total motor gasoline demand by Census Division
pr = petroleum product index 1 through 20
cd = Census Division 1 through 9
t = total (across CD) product demand index, 11, for product pr

A composite national average gasoline price is estimated by:

$$PALMG_{t,yr} = \sum_{prx=2,3,4,5} (PMG(pr)_{t,yr} * MGDMD(prx) / MGDMDGT)$$

$$RFDLMG_{t,yr} = \sum_{prx=2,3,4,5} ((RFDL(pr)_{t,yr} * MGDMD(prx) / MGDMDGT)$$

where:
PALMG = national weighted average gasoline price, with markups
RFDLMG = national weighted average gasoline price, without markups
PMG(pr) = refinery gate price of motor gasoline product pr
MGDMD(t) = national demand for each gasoline type (t)
MGDMDGT = total national motor gasoline demand
RFDL(pr) = refinery marginal prices for motor gasoline (pr) product only
pr = motor gasoline ID
prx = motor gasoline index, 2,3,4,5
yr = NEMS year index
t = total (across CD) product demand index, 11, for product pr

(DSTCPMM) Estimate atmospheric distillation capacity and refinery utilization.

Purpose: Extracts capacity expansion information from LP. Estimates annual distillation capacity, utilization, and annual and cumulative capacity expansion. Totals refinery region (1=PADD I, 2=PADD's II,III,IV, 3=PADD V) estimates to national estimates.

Equations: Refinery distillation capacity is defined as a percentage (ranging from 93 percent to 96 percent for *AEO2003*) of total capacity to account for over-optimization in the LP. Units are converted to MMBCD and the U.S. total is determined.

(COGNPMM) Estimate refinery cogeneration.

Purpose: Reads refinery capacity, investments, and generation from LP using the SCOLLP subroutine.

Equations: Results are shared out to Census Divisions, fuel categories, and self or grid categories. U.S. and PAD District totals are calculated. Estimates are converted to trillion Btu. PAD District level estimates for cogeneration, cogeneration capacity, refinery fuel consumption, generation for self and for the grid are then allocated to the various Census Divisions. The estimates for fuel consumption, capacity, generation are desegregated by fuel type and by generation to grid versus to self. Census Division estimates are summed to U.S. totals.

(ELPMMRD) Calculate electricity consumption data.

Purpose: ELPMMRD retrieves the electricity consumption activity from the LP using the SCOLLP subroutine.

Equations: Convert units to KWh and disaggregates refinery region (1=PADD I, 2=PADDs II,III,IV, 3=PADD V) data to the Census Divisions.

(PMMRFFU) Estimate refinery fuel use.

Purpose: Estimates refinery consumption of distillate, residual fuel, coal, LPGs, natural gas, still gas, petroleum coke, and other petroleum products by refinery regions (1=PADD I, 2=PADDs II,III,IV, 3=PADD V).

Equations: Retrieve fuel use values from the LP using the SCOLLP subroutine and converts units to MMBtu. Sums refinery region data to U.S. totals and determines total U.S refinery petroleum fuel use minus natural gas fuel use.

(RPTAKGTL) Retrieve Alaska GTL production and natural gas consumption for GTL production from model results (for reporting).

Purpose: This subroutine retrieves the GTL-related information from the LP solution and processes it into variables for reporting.

Equations: Retrieves natural gas consumption results from the LP solution, total across steps, convert to BCF/yr, and stores in the report variable AKGTL_NGCNS. Retrieves GTL production levels from the LP solution, totals across types, and stores in the report variable Q_GTLPROD.

(RPTRFCTL) Retrieve CTL production and coal consumption used for CTL production from model results for (reporting).

Purpose: This subroutine defines the CTL production level and the corresponding coal consumption level used in reports.

Equations: CTL processing level results are retrieved from the LP solution to define the CTL production level. It also retrieves the coal consumption level from the CTL coal supply curve results and defines the corresponding coal consumption level. Coal prices are obtained from the dual on the coal balance constraint, reduced by the coal transfer costs.

(RFDMDFU) Convert refinery fuel use to Census Division demands.

Purpose: Converts refinery region (1=PADD I, 2=PADDs II,III,IV, 3=PADD V) level estimates for refinery consumption to Census Division demands.

Equations: Calculates refinery fuel consumption in each Census Division based on refinery region estimates.

(PMMOUTP) Update the Common Block Variables

Purpose: Updates a number of NEMS common block price and volume variables whose values are determined by output of the PMM LP. This subroutine is run each NEMS iteration.

Equations: Various values are sequentially pulled out of the LP solution area, and corresponding common block variables are set to various functions of the solution values.

The row matrix solution values accessed are activity, slack, lower bound, upper bound, and pi. The column values are for activity, cost, lower bound, upper bound, and DJ. For instance, the common block variable to be updated may be total product imports. Then the activity for the LP row that controls product imports is obtained from the solution and the corresponding common block variable is set equal to that value adjusted for any difference in units of measure.

(PMMOUT3) Update Common Block Variables

Purpose: Updates the PMM and NEMS system common block values of refinery production volumes by NEMS refinery product and by PAD District. Also updates the total U.S. production volumes by product. This is done at each iteration for every projection year.

Equations: Row activity solution values of the PMM LP, representing total refinery production by refining region (1=PADD I, 2=PADDs II,III,IV, 3=PADD V) and by refined product are sequentially read; and, corresponding common block variables are set to the matrix solution values or to sums of several values as appropriate.

(DCRDPRC) Retrieves domestic crude marginal prices from the LP solution.

Purpose: DCRDPRC retrieves the margin values of domestic crude by OGSM region and crude type by using the SROWLP subroutine.

Equations: None.

(WCNVFCT) Calculates the heat rates for petroleum product imports and exports and motor gasoline.

Purpose: WCNFCT calculates the quantity weighted average heat rates for petroleum product imports and exports, natural gas liquids, and motor gasoline.
Equations: The heat rate for imported petroleum product is calculated using the weighted average of each product's heat rate. This calculation is also performed for the exported petroleum product's heat rate and the natural gas liquids average heat rate. Each motor gasoline's heat rate is used to calculate the quantity weighted average aggregate gasoline heat rate.

(DOMU) Calculate end-use prices by sector .

Purpose: DOMU breaks wholesale petroleum products prices into sectoral end-use product prices.

Equations: Sectoral end-use prices are calculated by adding two sectoral markups, one for taxes the other for transportation costs, to the refinery gate prices for each petroleum product. Units are converted to $/MMBTU and the motor gasoline price is calculated as the quantity weighted average price of the four motor gasoline types.

(FCCMODOP) Retrieves the fluid catalytic crackers' modes of operations activity level from the LP solution.

Purpose: This subroutine retrieves the activity level from the FCC modes of operations columns in the LP solution.

Equations: None.

(ALKMODE) Retrieves the utilizations for the alkylation units' modes of operation.

Purpose: This subroutine retrieve the activity amount for each alkylation mode of operation from the LP solution.

Equations: None.

(GETPMMO) Retrieve objective function values from the LP solution.

Purpose: This subroutine retrieves the objective function value from the LP solutions for reporting in the detailed PMM reports.

Equations: None.

(RFCAPX) Calculate refinery capital expenditure.

Purpose: RFCAPX calculates refinery capital expenditure.

Equations: $RFREV_{yr} = RFREV_{yr-1} * 1.023$

where:
RFREV = refinery revenue
yr = NEMS year
1.023 = growth rate

(MGSPCDL) Retrieves motor gasoline specification information.

Purpose: This subroutine retrieves the motor gasoline specifications LP row status and dual value for reporting.

Equations: None.

(PMM_HH2RPT) Defines hydrogen produced and consumed at the refinery, for reporting.

Purpose: This subroutine defines hydrogen production and consumption at the refinery and puts the information into variables for reporting.

Equations: Yield and consumption coefficients, processing levels, and other factors are used to calculate hydrogen production and consumption at the refinery. Units producing and consuming hydrogen had to be identified.

4.4 Capacity Expansion Subroutine

Section 4.4 describes the function of the subroutines in figure 4.4, preprocessing the PMM matrix for capacity expansion expectation.

(XPMMLP) Set up and solve expected PMM LP for capacity expansion loop.

> Purpose: XPMMLP calls subroutines to set up the LP for the capacity expansion look ahead year, solves the LP, and writes the basis for that solution.
>
> Equations: None.

(CHGPUINV) Update processing unit investment capacities bounds.

> Purpose: CHGPUINV updates the processing unit investment and cumulative build bounds in the LP during the capacity expansion iteration.
>
> Equations: Processing unit investments are upper bounded by 1000 Mbbl/cd and cumulative builds are fixed bounded based on the processing unit builds to date.

(CHGBLDLIM) Set initial capacity build limit

> Purpose: CHGBLDLIM sets the initial capacity build limit to correspond to the flags set in the qdcrdcf.txt input file.
>
> Equations: None.

The remainder of the subroutines in figure 4.4 have been presented in section 4.2, the matrix preprocessing subroutine.

4.5 OML Specific Subroutines

Additional subroutines used to perform Optimization Modeling Library (OML) specific LP matrix operations during the matrix pre- and post-processing are presented below.

(CBNDLP) Updates LP column bounds.

Purpose: The LP column bounds are updated with using the OML function WFCBND.

Equations: None.

Data Passed: COLNAME, column name, LWBD, lower bound, UPBD, upper bound

(CNAMELP) Retrieves LP column name.

Purpose: Retrieves LP column name using the OML function WFCNAME.

Equations: None.

Data Passed: I, column index, NAME, column name

(CRHSLP) Updates a LP RHS with the specified value.

Purpose: Updates an LP matrix RHS using the OML function WFCRHS

Equations: None.

Data Passed: COLNAME, column name, RHSVAL, right hand value

(CVALLP) Updates coefficient value in the LP matrix.

Purpose: Updates coefficient value in the LP matrix using the OML function WFCVAL.

Equations: None.

Data Passed: COLNAME, column name, ROWNAME, row name, VAL, coefficient value

(RVALLP) Retrieves coefficient value in the LP matrix.

Purpose: Retrieves coefficient value in the LP matrix using the OML function WFRVAL.

Equations: None.

Data Passed: COLNAME, column name, ROWNAME, row name, VAL, coefficient value

(MPSINLP) Loads the PMM LP matrix file into an OML matrix file.

Purpose: This subroutine calls an OML function which reformats an MPS formatted file into an OML LP matrix format.

Equations: None.

(PUNCHLP) Saves the current basis to a file.

Purpose: Saves the current basis to a file using the OML function WFPUNCH.

Equations: None.

(RBNDLP) Retrieves bound values from a column.

Purpose: Retrieves bound values from a column using the OML WFRBND function.

Equations: None.

Data Passed: COLNAME, column name, LWBD, lower bound, UPBD, upper bound

(RNAMELP) Retrieves row names from the matrix LP.

Purpose: Retrieves row names from the matrix LP using the OML function WFRNAME.

Equations: None.

Data Passed: I, row index, NAME, row name

(SCOLLP) Retrieves solution column values from the LP solution.

Purpose: Retrieves solution column values from the LP solution using the OML function WFSCOL.

Equations: None.

Data Passed: COLNAME, column name, SLCT selected range, STATC, status value,VALUE, values

(SROWLP) Retrieve the current solution row from memory.

Purpose: Retrieves the current solution row from memory using the OML function WFSROW, which retrieves the specified solution (activity, slack, lower limit, upper limit, PI value) and status (basic, upper limited, lower limited, equal, free) into a predefined array.

Equations: None.

APPENDIX A

PMM Data and Outputs

APPENDIX A PMM Data and Outputs

This appendix is divided in three parts; Section A.1 lists the variables and definitions used in the PMM, Section A.2 lists the data sources, and Section A.3 lists the data tables (and their structures) used by the MRM (Multi-Refining Model) to create the initial PMM matrix that is loaded into the NEMS environment. These data tables constitute the major portion of the PMM data as they represent the refining process unit technology and capacities, quality characteristics, and specifications used in each of the refining regions (beginning with *AEO98*, 1= PADD I, 2= PADDs II,III,IV, 3= PADD V).

A.1 PMM Variables and Definitions

This section presents the PMM variable names and definitions associated with the linear programming (LP) matrix, PMM outputs, PMM inputs, and internally used variables.

A.1.1 PMM LP and NEMS Variable Names Cross References

A cross reference listing between the PMM LP matrix names and NEMS variable names is shown in Table A1. The dimensional units are based on the PMM LP variables. The NEMS variable units may vary to conform to NEMS standards.

Table A1. PMM/NEMS Cross References

PMM LP Variable	LP Units	NEMS Variable
A (cd) G08TRH	Mbbl/cd	SBG08TRH, RFETHMGS(MMbbl/cd)
A (cd) G08TRG	Mbbl/cd	SBG08TRG, RFETHMGS(MMbbl/cd)
A (cd) G08RFH	Mbbl/cd	SBG08RFH, RFETHMGS(MMbbl/cd)
A (cd) G08RFG	Mbbl/cd	SBG08RFG, RFETHMGS(MMbbl/cd)
A (pd) (prd)	Mbbl/cd	RFDPRD(prd),QPRDRF
A (pd) SST	Mbbl/cd	RFDPRDTRG, QPRDRF
A (pd) SSR	Mbbl/cd	RFDPRDRFG, QPRDRF
A (pd) SSE	Mbbl/cd	RFDPRDTRG, QPRDRF
A (pd) STM	M lb /cd	STMDMD
A (pd) ETHRFN (incl merchant)	Mbbl/cd	RFETHETB(net merchant)(MMbbl/cd)
A (pd) (gbc)RFG	Mbbl/cd	RFGBCRFG
A (pd) (gbc)TRG	Mbbl/cd	RFGBCTRG
A@CRDDCR	Mbbl/cd	RFCRDDCR
A@CRDEXP	Mbbl/cd	RFQEXCRD
A@CRDL48	Mbbl/cd	RFCRDL48
A@CRDAKA	Mbbl/cd	RFCRDAKA
A@CRDTOT	Mbbl/cd	RFCRDTOT (MMbbl/cd)
A@CRDFCR	Mbbl/cd	RFQICRD (MMbbl/cd)
A@ETHPRD	Mbbl/cd	RFETHD (MMbbl/cd)
A@FUEL	Mbbl/cd	QCDUPD (MMbbl/cd)
A@GAIN	Mbbl/cd	RFQPRCG (MMbbl/cd)
A@INVST	M$87/cd	RFCAPEXP (or 0 or 50000)
A@MTBIMP	Mbbl/cd	RFMTBI (MMbbl/cd)

NAME	LP Units	NEMS Variable
A@METIMP	Mbbl/cd	RFMETI (MMbbl/cd)
A@METDEM	Mbbl/cd	RFMETCHM (MMbbl/cd)
A@METM85	Mbbl/cd	RFMETM85 (MMbbl/cd)
A@NGFTOT	Mbbl/cd	RFNGFTOT
A@NGLPRD	Mbbl/cd	RFPQNGL (MMbbl/cd)
A@NGLRFN	Mbbl/cd	RFQNGLRF, NGLRF (MMbbl/cd)
A@NGSH2P	Mbbl/cd	OTHOXY (MMbbl/cd)
A@PRDEXP	Mbbl/cd	RFQEXPRDT (MMbbl/cd)
A@PRDIMP	Mbbl/cd	RFPQIPRDT (<9900) (MMbbl/cd)
A@PETCOK	Mbbl/cd	RFQPRCG (MMbbl/cd)
A@UNFIMP	Mbbl/cd	RFPQUFC (MMbbl/cd)
B (pd) TRGMTB, B(r)RFGMTB	Mbbl/cd	RFGPRD(mg)
B (pd) TRGETH, B(r)RFGETH	Mbbl/cd	BLDETHRF
B (pd) ETB	$87/bbl	PETB
B (pd) TAE	$87/bbl	PTAE
B (pd) THE	$87/bbl	PTHE
B (pd) MTB	$87/bbl	PMTB25
B (pd) THM	$87/bbl	PTHM
B (pd) TAM	$87/bbl	PTAM
B (pd) SRI	$87/bbl	PSRI
B (pd) FC8	$87/bbl	PFC8
B (pd) R10	$87/bbl	PR10
B (pd) ALB	$87/bbl	PALB
B (pd) KHL	$87/bbl	PKHL
B (pd) 2HL	$87/bbl	P2HL
B (pd) RSI	$87/bbl	PVAF
B (pd) (oxy)	$87/bbl	P(oxy)RFBL
B (pd) IC4	$87/bbl	PGPLTRF
B (pd) NC4	$87/bbl	PGPLTRF
CAA (crd)	$87/bbl	PCRDRF, RFDCRDP, CRDTYPEP,WLLHDPR
C (pd) D (crdtype)	$87/bbl	PCRDRF,RFDCRDP,CRDTYPEP,WLLHDPR
C (cd) ETHR (q(k))	Mbbl/cd,[$87/bbl]	WQETOH,SQETOH,CRNETHCD,[CRNCSTCD]
C (cd) ETCR (q(k))	Mbbl/cd,[$87/bbl]	WQETOH,SQETOH,CLLETHCD,CLLCAPCD, [CLLCSTCD]
C (cd) BIMR (q(k))	Mbbl/cd	BIMSUP
C(pd)CTLTOT	Mbbl/cd	Q_CTLPRD, RFCTLPRD
C (pd) F (crdtype)	$87/bbl	PCRDRF
D (cd) ETH	$87/bbl	PETHANOL,RENADJPR, RENETHPR
D (cd)(prd) N (q(K))	Mbbl/cd,$87/bbl	QN,PN
D (cd)(prd) P (q(k))	Mbbl/cd,$87/bbl	QP,PP
D (cd)(prd) S1	Mbbl/cd	PRDDMD
D (cd) (prd) SX	Mbbl/cd	QPRDEX
D (cd) COKSX	$87/bbl, [Mbbl coe/cd]	RFWOP, PCOKH, [RFQEXPRDT (MMbbl coe/cd)]
D (cd) (prd) Z9	Mbbl/cd, [87$/bbl]	QPRDEXD, [RFWOP,WOPZ9EXP]
D (cd) COKZ9	$87/bbl	RFWOP, PCOKH, PRCPCNT
D (cd) (prd)	$87/bbl	RFDL (prd)
D (cd) (mogas)	$87/bbl	RFGT(mogas), RFGTMG
D@METS1	Mbbl/cd	PRDDMDME
E (pd) ACUINV	Mbbl/cd	RFDSTCAP, RFDSTUTL, RFDSCUM (MMbbl/cd)
E (pd) CGNINV	Mkwh/cd	EINVPD
E (pd) CGXINV	Mkwh/cd	EXINVPD
E (pd) (prcunit)INV	Mbbl/cd	PUBASEUT, PUBASE, PUINV, or Constants of 0, 1000
E (pd) (emissn) (emisst)	MMton/yr	RFEMISST
G (pd) CC3LPG	Mbbl/cd	QGPLTRF
G (pd) IC4LPG	Mbbl/cd	QGPLTRF

NAME	LP Units	NEMS Variable
G (pd) NC4LPG	Mbbl/cd	QGPLTRF
G (pd) NATOTH	Mbbl/cd	QGPLTRF
G (pd) NATPCF	Mbbl/cd	QGPLTRF
G (pd) DGR	Bcf/cd	QGPLTRF
G (pd) GPL01	Bcf/cd	QGPLTRF
G (pd) IC4RFN	Mbbl/cd	QGPLTRF
G (pd) MOH01	Mbbl/cd	RFMETD (MMbbl/cd), RFMETETH (MMbbl/cd)
G (pd) NC4RFN	Mbbl/cd	QGPLTRF
G (pd) NATRFN	Mbbl/cd	QGPLTRF
G (pd) PGSLPG	Mbbl/cd	QGPLTRF
G (pd) SC2CC1	Mbbl/cd	QGPLTRF
G (pd) SC3CC1	Mbbl/cd	QGPLTRF
G (pd) METRFN	Mbbl/cd	QMETRFN
H (pd) RFMPEH	Mbbl/cd	RFETHMCT (MMbbl/cd)
H (pd) RFMPMT	Mbbl/cd	RFMETMCT (MMbbl/cd), RFMETETH (MMbbl/cd), QRFMPMT
H (pd) CTX(mod), H(pd)CTZ(mod)	Mbbl/cd	RFCTLLIQ
H (pd) ETXETB	Mbbl/cd	RFETBMCT (MMbbl/cd)
H (pd) ETXMTB	Mbbl/cd	RFMTBMCT (MMbbl/cd)
H (pd) GPMPI4	Mbbl/cd	QGPLTRF
H (pd) GPMPN4	Mbbl/cd	QGPLTRF
H (pd) SMD(mod), H(pd)SOD(mod)	Mbbl/cd	Q_GTLPRD
I (pd) (prd) Z9	Mbbl/cd	QPRDIMD
I (pd) (iprd) R (q(k))	Mbbl/cd,[$87/bbl]	QI(iprd), PI (iprd), QPRDIMP
I (pd) (iprd) R (q(k))	$87/bbl,Mbbl/cd	RFIPQ??, ITIM??SC, where ?? = LG GS RF LD DS RL RH JF OT PF
I (pd) MTBR (q(k))	Mbbl/cd	RETHRIMP
K (pd) (prcunit) CAP	Mbbl/cd	PUBASEUT, PUBASE
K (pd) ACUCAP	Mbbl/cd	DSTCAP, DSTUTL, RFBDSTCAP (MMbbl/cd)
K (pd) CGNCAP	Mkwh/cd	RFCGCAPPD (MW)
K (pd) CGXCAP	Mkwh/cd	RFCXCAPPD, RFCGCAPPD (MW)
K (pd) FGSCAP	Mbbl/cd	FGS_UL, FGS_SOL
L (pd) (prcunit)BLD	Mbbl/cd	PUBASEUT, PUBASE, PUCUM , PUINV, 0.0
L (pd) ACUBLD	Mbbl/cd	RFDSTCAP, RFDSTUTL,RFDSCUM (MMbbl/cd)
L (pd) CGNBLD	Mkwh/cd	LBLDPD
L (pd) CGXBLD	Mkwh/cd	LXBLDPD
L (pd) CTXBLD	Mbbl/cd	CTLBLT
M (pd) (prd)	$87/bbl	RFGT (prd)
N (pd) (coal) (q(k))	Mton/cd, 87$/ton	Q_CTLCOAL, QCLRFPD (tril Btu/yr), P_CTLCOAL, CLMINEP
N (pd) NGKN (q(k))	Mbbl foe/cd	AKGTL_NGCNS(BCF/yr), AKNG_SUPCRV(BCF/yr), Q_GTLGAS
N (pd) NGRFP (q(k))	MMcf/cd	NGRFUPIT, NGRFUTOT
N (pd) NGRFN (q(k))	MMcf/cd	NGRFUPIT, NGRFUTOT
N (pd) DGP	Bcf/day	PRNG_PADD, QNGPD
NZAMHP(q(k)), NZAMHN(q(k))	Mbbl/cd	ALKEXPTOT
M (pd) (prd)	$87/bbl	RFGT (prd)
OBJ	M $87./bbl	PMMOBJ
O@CRDSPR	Mbbl/cd	RFSPRFR
O@CRDEXP	Mbbl/cd	QEXCRDIN
P (pd) COK	Mbbl/cd	QCDUPD, RFQPRCG, QCOKFU (MMbbl/cd)
PANGLQ1	Mbbl/cd	QGPLTRF, OGNGLAK
P (og) DCRQ1	Mbbl/cd	RFQTDCRD
P (pd)F(crdtype)Q(q(k)	Mbbl/cd,$87/bbl	RFIPQC (crdtype), QICRD, PICRD, Q_ITIMCRSC
P (pd) PFU	MFOED	PRPFU(5)
P (pd) PFF	MFOED	PRPFF(5)
Q (pd) RFG (spec)	$87/bbl	RFGSPCDL
Q (pd) TRG (spec)	$87/bbl	TRGSPCDL

NAME	LP Units	NEMS Variable
Q(pd)(prd)(spec)(minmax)	Many	MGSPCS
R (pd) ALK (mode)	Mbbl/cd	ALKACT
R (pd) ACUF (crdtype)	Mbbl/cd	QCRDRF
R (pd) ACUD (crdtype)	Mbbl/cd	QCRDRF
R (pd) ACUA (crdtype)	Mbbl/cd	QCRDRF
R (pd) CGNCGN	M kwh/cd	RFCGGENPD
R (pd) CGXCGN	M kwh/cd	RFCXGENPD
R (pd) ETHMTB	Mbbl/cd	RFMTBD (MMbbl/cd)
R (pd) ETHETB	Mbbl/cd	RFETBD (MMbbl/cd)
R (pd) ETMTAE	Mbbl/cd	RFTAED (MMbbl/cd)
R (pd) ETMTAM	Mbbl/cd	RFTAMD (MMbbl/cd)
R (pd) ETMTHE	Mbbl/cd	RFTHED (MMbbl/cd)
R (pd) ETMTHM	Mbbl/cd	RFTHMD (MMbbl/cd)
R (pd) FUMN2H	Mbbl/cd	QDISFU
R (pd) FCC(mod)	Mbbl/cd	FCC (mod), FCCACT, FCCDUAL (87$/bbl)
R (pd) FUMN6I	Mbbl/cd	QRESFU
R (pd) FUMN6A	Mbbl/cd	QRESFU
R (pd) FUMN6B	Mbbl/cd	QRESFU
R (pd) FUMCC3	Mbbl/cd	QLPGFU
R (pd) FUMUC3	Mbbl/cd	QLPGFU
R (pd) FUMIC4	Mbbl/cd	QLPGFU
R (pd) FUMUC4	Mbbl/cd	QLPGFU
R (pd) FUMNC4	Mbbl/cd	QLPGFU
R (pd) FUMC2E	Mbbl/cd	QSTGFU
R (pd) FUMPGS	Mbbl/cd	QSTGFU
R (pd) FUMCC2	Mbbl/cd	QSTGFU
R (pd) FUMCC2	Mbbl/cd	QSTGFU
R (pd) FUMPGU	Mbbl/cd	QSTGFU
R (pd) FUMPGX	Mbbl/cd	QSTGFU
R (pd) FUMPGT	Mbbl/cd	QSTGFU
R (pd) FUMNGS	Mbbl/cd	QNTGFU, 0-99999
R (pd) FUM (rfothfu)	Mbbl/cd	QOTHFU
R (pd) FUM (pnfut)	Mbbl/cd	RFFMT
TAGTLTOT	Mbbl/cd	AKGTLPRD, MINGTLNS
T(r)OVCOBJ	1000 $87/cd	RFOPEXP
T (pd) UNFNPP	$87/bbl	RFWOP, NPPCOEF
T (pd) UNFHGM	$87/bbl	RFWOP, HGMCOEF
T (pd) UNFARB	$87/bbl	RFWOP, ARBCOEF
U (pd) KWH (column)	Mkwh/cd	RFELPURPD (MMkwh/cd)
U (pd) KWH (row)		
U (pd) KWH (obj)		
U (pd) NGF	$87/MMcf	PRFNGFU, PGININ, OGWPRNG
VTPC (crd)	Mbbl/cd	FLOWCRD, CAPCRD
VTPP (crd)	Mbbl/cd	FLOWPRD, CAPCRD
VTPL (crd)	Mbbl/cd	FLOWLPG, CAPLPG
W (pd) (prd) J (cd)	Mbbl/cd	FLOWPD_CT
W (pd) (prd) 4 (cd)	Mbbl/cd	FLOWPD_DT
W (pd) (prd) B (cd)	Mbbl/cd	FLOWPD_CB
W (pd) (prd) V (cd)	Mbbl/cd	FLOWPD_EBD
W (pd) (prd) O (cd)	Mbbl/cd	FLOWPD_LT
W3ETH(m)(pd), W4ETH(m),(pd)	Mbbl/cd	QETHRFN
X (pd) CKLCOK	$87/bbl	RFWOP, PCOKL
X (pd) CKHCOK	$87/bbl	RFWOP, PCOLH
X (pd) SULSAL	1000 sTon/cd	QSULSAL
X (cd) ETHE85	Mbbl/cd	RFETHE85 (MMbbl/cd), ETHE85CD
X (cd) ETHRFG	Mbbl/cd	SBRFGRFG
X (cd) ETHRFH	Mbbl/cd	SBRFGRFH
NAME	**LP Units**	**NEMS Variable**

X (cd) ETHTRG	Mbbl/cd	SBTRGTRG
X (cd) ETHTRH	Mbbl/cd	SBTRGTRH
ZZAMHTOT	Mbbl/cd	Function of WOP
Z (cd) ETHTAX	Mbbl/cd, $87/bbl	CORNETH, CORNSUB
Z (cd) ETCTAX	Mbbl/cd, $87/bbl	CELLETH, CELLSUB
Z@IRACX	$87/bbl	RFWOP
Z@IRACN	$87/bbl	RFWOP
Z@TOTCRD	$87/bbl	RFWOP, IRACN, IRACX

Legend for Codes

Code	Name	Values	No. in Set
(cd)	Census Divisions	1-9	9
(coal)	Coal Types	regional	3
(crdtype)	Crude Types	LL-HV	5
(emissn)	Emissions	VOC-CAR	6
(emisst)	Combustion/Noncombustion	C,N	
(gbc)	Gasoline Blend Component	00-12	13
(iprd)	Imported Products	LPG-DSL	12
(minmax)	Minimum or Maximum	N,X	
(mod)	Operating mode	many	many
(oxy)	Oxygenate	ETH, MET, MTB	3
(og)	Oil and Gas Divisions	1-6,A	7
(pd)	Refinery Regions	E,B,W (*AEO2001*)	3-5
(pnfut)	Refinery Fuels	NGS-JNH	30
(prcunit)	Process Units	ACU-PFA	37
(prd)	Products	LPG-M85	20
(q(k))	Quantities	1-9	9
(rfothfu)	Refinery Fuel for Other	JIH-NPN	19
(spec)	Product Specificatons	RV-BZ	6

Code	Name	Values
DS	Imported product	Distillate
GS	Imported product	Conventional mogas
JF	Imported product	Jet Fuel
LD	Imported product	Low sulfur diesel
LG	Imported product	LPG
OT	Imported product	Other
PF	Imported product	Petrochemical Feeds
RF	Imported product	Reformulated mogas
RH	Imported product	High sulfur residual
RL	Imported product	Low sulfur residual

A.1.2 PMM Output Variables

REFINERY MODULE OUTPUT VARIABLES (pmmout)

NAME	UNITS	DEFINITION
AKGTLEXP(MNUMYR)	Mbbl/cd	GTL exported from Alaska
AKGTLPRP(MNUMYR)	Mbbl/cd	GTL produced in Alaska
AKGTL_NGCNS(MNUMYR)	BCF	Natural gas consumed in GTL process
DCRDWHP(MNUMOR,MNUMYR)	$87/bbl	Dometic crude wellhead price
PCTPLT_PADD(MNUMPR,MNUMYR)	BCF	Gas plant fuel cons./Total NG production
QCLRFPD(MNUMPR,MNUMYR)	Tril BTU/yr	Quantity of coal for CTL
RFCAPEXP(MNUMYR)	MM$87/Day	Rf capital expenditures
NAME	**UNITS**	**DEFINITION**
RFCTLPRD(MNUMYR)	Mbbl/Day	Quantity of liquids from coal
RFDCRDP(MNUMOR,MNUMYR,5)	$87/bbl	Domestic crude price by crude type
RFPQNGL(MNUMPR,MNUMYR,6,2)	$87/bbl,Mbbl/cd	Prc/quan of ngl by PAD district
RFQDCRD(MNUMOR+2,MNUMYR)	MMbbl/yr	Domestic conventional crude
RFQDINPOT(MNUMPR,MNUMYR)	MMbbl/cd	Quantity other input to refin.
RFQPRCG(MNUMPR,MNUMYR)	MMbbl/cd	Quantity of processing gains
RFQPRDT(MNUMCR, MNUMYR)	MMbbl/cd	Total product supplied
RFQTDCRD(MNUMOR+2,MNUMYR)	MMbbl/yr	Total domestic crude (incl EOR)
RFREV(MNUMYR)	MM87$87/Day	Refinery revenues
RFSAL(MNUMYR)	Tons/yr	Sulfur allowances
RFSPRFR(MNUMYR)	MMbbl/cd	Rf spr fill rate
RFSPRIM(MNUMYR)	MMbbl/cd	Spr imports
XDCRDWHP(MNUMOR,MNUMYR)	$87/bbl	Expected domestic crude wellhd price
XRFQDCRD(MNUMOR,MNUMYR)	MMbbl/yr	Expected domestic crude production

REFINERY REPORT OUTPUT VARIABLES (pmmrpt)

NAME	UNITS	DEFINITION
BLDIMP(MNUMPR,MNUMYR)	MMbbl/cd	Blending component imports
CLLETHCD(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol produced from cellulose
CRNETHCD(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol produced from corn
DSMURS(MNUMCR,MNUMYR,2)	$87/bbl	Residential Distillate Markups
DSMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Distillate Markups
DSSTTX(MNUMCR)	$87/bbl	Diesel State Tax
JFMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Jet Fuel Markups
JFSTTX(MNUMCR)	$87/bbl	Jet Fuel State Tax
MGMUTR(MNUMCR,MNUMYR,2)	$87/bbl	Transportation Gasoline Markups
MGSTTX(MNUMCR)	$87/bbl	Gasoline State Tax
MUFTAX(MNUMYR,15)	$87/MMBtu	Federal motorgasoline tax
PALMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline all combined
PDS(MNUMCR,MNUMYR)	$87/bbl	Distillate fuel oil
PDSL(MNUMCR,MNUMYR)	$87/bbl	Low sulfur diesel
PJF(MNUMCR,MNUMYR)	$87/bbl	Jet fuel
RFBDSTCAP(MNUMPR,MNUMYR)	MMbbl/cd	Refinery base distillation capacity
RFCGCAPADDPD(MNUMPR,MNUMYR)	kW/yr	Cogen. capacity by PAD District
RFCGCAPCD(MNUMCR,NMUMYR)	mW	Cogen. capacity by Cen. Div.
RFCGCAPPD(MNUMPR,MNUMYR)	mW	Cogen. capacity by PAD District
RFCRDOTH(MNUMPR,MNUMYR	MMbbl/cd	Other crude imports by PAD District
RFDPRDAST(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; asphalt & road oil
RFDPRDCOK(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petroleum coke
RFDPRDDSL(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; low sulfur diesel
RFDPRDDSU(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; ultra low sulfur diesel
RFDPRDJTA(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; jet fuel
RFDPRDKER(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; kerosene

RFDPRDLPG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery production; LPG
RFDPRDN2H(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; no. 2 distillate
RFDPRDN6B(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; high sulfur oil
RFDPRDN6I(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; low sulfur resid oil
RFDPRDOTH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; other petroleum
RFDPRDPCF(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; petrochemical feeds
RFDPRDRFG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; reformulated mogas
RFDPRDRFH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; reform. hi oxyg. mogas
RFDPRDSTG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; still gas
RFDPRDTRG(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; motor gasoline
RFDPRDTRH(MNUMPR,MNUMYR)	Mbbl/cd	Refinery prd; high oxygenated mogas
RFDPRDTRL(MNUMPR,MNUMYR)	Mbbl/cd	Domestic Production of Low Sulfur Gasoline
NAME	**UNITS**	**DEFINITION**
RFDSTCAP(MNUMPR,MNUMYR)	Mbbl/cd	Refinery distillation capacity
RFDSTUTL(MNUMPR,MNUMYR)	Percent	Capacity utilization rate
RFDSCUM(MNUMPR,MNUMYR)	MMbbl/cd	Processin unit cumulative cap. expansion
RFELPURPD(MNUMPR,MNUMYR)	$87/kWh	Electricity purchased by PAD District
RFENVFX(MNUMCR,MNUMYR,20)	$87/bbl	Refinery Environmental Fixed Costs
RFETHD(MNUMYR)	MMbbl/cd	Domestic ethanol
RFETHE85(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for E85 production
RFIMCR(MNUMPR,MNUMYR)	MMbbl/YR	Crude net imports
RFIMTP(MNUMPR,MNUMYR)	MMbbl/YR	Total prod net imports
RFIPQCHH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur heavy
RFIPQCHL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur light
RFIPQCHV(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-high sulfur very heavy
RFIPQCLL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-low sulfur light (P,Q)
RFIPQCMH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Import crude-medium sulfur heavy
RFIPQDL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported low sulfur distillate (P,Q)
RFIPQDS(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports distillate (P,Q)
RFIPQJF(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports jet fuel (P,Q)
RFIPQLG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports lpg (P,Q)
RFIPQME(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports methanol (P,Q)
RFIPQMG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports motor gasoline (P,Q)
RFIPQMT(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports mtbe (P,Q)
RFIPQOT(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported other (P,Q)
RFIPQPF(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported petrochem feeds (P,Q)
RFIPQRG(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imported reformulated mogas (P,Q)
RFIPQRL(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports low sulfur resid (P,Q)
RFIPQRH(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Imports high sulfur resid (P,Q)
RFMETCHM(MNUMPR,MNUMYR)	MMbbl/cd	Chem. Demand for methanol
RFMETD(MNUMYR)	MMbbl/cd	Domestic methanol
RFMETI(MNUMPR,MNUMYR)	MMbbl/cd	Imported methanol
RFMETM85(MNUMPR,MNUMYR)	MMbbl/cd	Methonal for M85 production
RFMTBI(MNUMPR,MNUMYR)	MMbbl/cd	Imported MTBE
RFMTBD(MNUMPR,MNUMYR)	MMbbl/cd	Domestic MTBE production.
RFPQIPRDT(MNUMPR,MNUMYR,2)	$87/bbl,MMbbl/cd	Total imported product
RFPQUFC(MNUMPR,MNUMYR,2)	MMbbl/cd	Total imports of unfinished crude
RFQARO(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of asphalpt and road oil
RFQDS(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of distillate fuel oil
RFQEL(MNUMYR)	MMbbl/cd	Utility product demand
RFQEXCRD(MNUMPR,MNUMYR)	MMbbl/cd	Crude exported
RFQEXPRDT(MNUMPR,MNUMYR)	MMbbl/cd	Total product exported
RFQICRD(MNUMPR,MNUMYR)	MMbbl/cd	Imported total crude
RFQIN(MNUMYR)	MMbbl/cd	Industrial product demand
RFQJF(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of jet fuel
RFQKS(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of kerosene
RFQLG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of lpg

RFQMG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of motor gasoline
RFQOTH(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of other
RFQPCK(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of petroleum coke
RFQPF(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of petrochem feedstocks
RFQRC(MNUMYR)	MMbbl/cd	Residential/Commercial product demand
RFQRH(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of resid high sulfur
RFQRL(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of resid low sulfur
RFQSECT(MNUMYR)	MMbbl/cd	Total sectoral demand
RFQSTG(MNUMCR,MNUMYR)	MMbbl/cd	Quantity of still gas
RFQTR(MNUMYR)	MMbbl/cd	Transportion product demand

PRICE VARIABLES (mpblk)

NAME	UNITS	DEFINITION
PASIN(MNUMCR,MNUMYR)	$87/MMBtu	Asphalt, Road Oil, Industrial
PDSAS(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, All Sectors
PDSCM(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Commercial
PDSEL(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Electricity (+petroleum coke)
PDSIN(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Industrial
PDSRS(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Residential
PDSTR(MNUMCR,MNUMYR)	$87/MMBtu	Distillate, Transportation
PETTR(MNUMCR,MNUMYR)	$87/MMBtu	Ethanol, Transportation
PJFTR(MNUMCR,MNUMYR)	$87/MMBtu	Jet Fuel, Transportation
PKSAS(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, All Sectors
PKSCM(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Commercial
PKSIN(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Industrial
PKSRS(MNUMCR,MNUMYR)	$87/MMBtu	Kerosene, Residential
PLGAS(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, All Sectors
PLGCM(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Commercial
PLGIN(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Industrial
PLGRS(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Residential
PLGTR(MNUMCR,MNUMYR)	$87/MMBtu	Liquid Petroleum Gases, Transportation
PMETR(MNUMCR,MNUMYR)	$87/MMBtu	Methanol, Transportation
PMGAS(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, All Sectors
PMGCM(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Commercial
PMGIN(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Industrial
PMGTR(MNUMCR,MNUMYR)	$87/MMBtu	Motor Gasoline, Transportation
POTAS(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Industrial
POTIN(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Industrial
POTTR(MNUMCR,MNUMYR)	$87/MMBtu	Other Petroleum, Transportation
PPFIN(MNUMCR,MNUMYR)	$87/MMBtu	Petrochemical Feedstocks, Industrial
PRHAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, All Sectors
PRHEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, Electricity
PRHTR(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, High Sulfur, Transp.
PRLAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, All Sectors
PRLCM(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Commercial
PRLEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Electricity
PRLIN(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Low Sulfur, Industrial
PRLTR(MNUMCR,MNUMYR)	$87/MMBtu	Resid. Fuel, Low Sulfur, Transportation
PRSAS(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, All Sectors
PRSCM(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Commercial
PRSEL(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Electricity
PRSIN(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Industrial
PRSTR(MNUMCR,MNUMYR)	$87/MMBtu	Residual Fuel, Transportation
PTPAS(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, All Sectors
PTPCM(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Commercial
PTPEL(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Electricity

PTPIN(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Industrial
PTPRF(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Refinery
PTPRS(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Residential
PTPTR(MNUMCR,MNUMYR)	$87/MMBtu	Total Petroleum, Transportation

QUANTITY VARIABLES (qblk)

NAME	UNITS	DEFINITION
QELRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Purchased Elec., Refinery
QNGRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Natural Gas, Refinery
QCLRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Coal, Refinery

COGEN VARIABLES (cogen)

NAME	UNITS	DEFINITION
CGRECAP(MNUMCR,MNUMYR,5,2,2)	mW	Refinery Cogen Capacity
CGREGEN(MNUMCR,MNUMYR,5,2)	gWh	Refinery Cogen Generation
CGREQ(MNUMCR,MNUMYR,5,2)	tBtu	Refinery Fuel Consumption

A.1.3 PMM Input Variables

QUANTITY VARIABLES (qblk)

NAME	UNITS	DEFINITION
QMGCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Motor Gasoline, Commercial
QMGTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Motor Gasoline, Transportation
QMGIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Motor Gasoline, Industrial
QMGAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Motor Gasoline, All Sectors
QJFTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Jet Fuel, Transportation
QDSRS(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Residential
QDSCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Commercial
QDSTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Transportation
QDSIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Industrial
QDSRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Refinery
QDSEL(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, Electricity (+petroleum coke)
QDSAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Distillate, All Sectors
QKSRS(MNUMCR,MNUMYR)	Tril Btu/Yr	Kerosene, Residential
QKSCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Kerosene, Commercial
QKSIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Kerosene, Industrial
QKSAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Kerosene, All Sectors
QLGRS(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, Residential
QLGCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, Commercial
QLGTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, Transportation
QLGIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, Industrial
QLGRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, Refinery
QLGAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Liquid Petroleum Gases, All Sectors
QRLCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, Commercial
QRLTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, Transp.
QRLIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, Industrial
QRLRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, Refinery
QRLEL(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, Electricity
QRLAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Low Sulfur, All Sectors
QRHEL(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, High Sulfur, Electricity
QRHAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, High Sulfur, All Sectors
QRSCM(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Commercial
QRSTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Transportation
QRSIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Industrial
QRSRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Refinery
QRSEL(MNUMCR,MNUMYR)	Tril Btu/Yr	Residual Fuel, Electricity
QPFIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Petrochemical Feedstocks, Industrial
QSGIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Still Gas, Industrial
QSGRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Still Gas, Refinery
QPCIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Petroleum Coke, Industrial
QPCRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Petroleum Coke, Refinery
QPCEL(MNUMCR,MNUMYR)	Tril Btu/Yr	Petroleum Coke, Electricity
QPCAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Petroleum Coke, All Sectors
QASIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Asphalt and Road Oil, Industrial
QOTTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Other Petr. Transp, (lubes, aviation gas)
NAME	**UNITS**	**DEFINITION**
QOTIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Other Petroleum, Industrial
QOTRF(MNUMCR,MNUMYR)	Tril Btu/Yr	Other Petroleum, Refinery
QOTAS(MNUMCR,MNUMYR)	Tril Btu/Yr	Other Petroleum, All Sectors
QMETR(MNUMCR,MNUMYR)	Tril Btu/Yr	Methanol Transportation
QETTR(MNUMCR,MNUMYR)	Tril Btu/Yr	Ethanol Transportation
QELIN(MNUMCR,MNUMYR)	Tril Btu/Yr	Purchased Elec., Industrial sector

INTERNATIONAL MARKET MODEL VARIABLES (intout)

NAME	UNITS	DEFINITION
IT_WOP(MNUMYR,2)	$87/bbl	World oil price (2--units)
Q_ITIMCRSC(MNUMYR,5,5,3)	Mbbl/cd	Crude import supply curve quant.
P_ITIMCRSC(MNUMYR,5,5,3)	$87/bbl	Crude import supply curve prices
	Imported Product Supply Curves (P,Q)	
ITIMRGSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Reformulated mogas
ITIMGSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Tradition mogas
ITIMDSSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Distillate
ITIMLDSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur distillate
ITIMLRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low sulfur. Resid.
ITIMHRSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	High sulfur Resid.
ITIMJFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Jet fuel
ITIMLPSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	LPG
ITIMPFSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Petchemical Feedstocks
ITIMOTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Other
ITIMMESC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Methanol
ITIMMTSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	MTBE
ITIMXGSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Low S Gasoline
ITIMXDSC(MNUMYR,5,3,2)	$87/bbl,Mbbl/cd	Ultra Low S Diesel

OIL AND GAS SUPPLY MODEL VARIABLES (ogsmout)

NAME	UNITS	DEFINITION
OGNGLAK(MNUMYR)	Mbbl/cd	NGL from Alaska
AKNG_SUPCRV(3,2,MNUMYR)	$87/mcf, Bcf	NG supply curve for GTL production in Alaska

NATURAL GAS TRANSMISSION AND DISTRIBUTION SUPPLY MODEL VARIABLES (ngtdmout)

NAME	UNITS	DEFINITION
PRNG_PADD(MNUMPR,MNUMYR)	Bcf/Yr	Total dry gas production (W/L&P)

PRICE VARIABLES (mpblk, efpout)

NAME	UNITS	DEFINITION
PELIN(MNUMCR,MNUMYR)	$87/MMBTU	Purch. Elec. Industrial
PNGIN(MNUMCR,MNUMYR)	$87/MMBTU	Natural Gas. Industria
PGIIN(MNUMCR,MNUMYR)	$87/MMBtu	Noncore industrial sector prices
PELAS(MNUMCR,MNUMYR)	$87/MMBtu	Avg electricity prices for all sectors l
PCLIN(MNUMCR,MNUMYR)	$87/ton	Coal Industrial prices

RENEWABLE VARIABLES (wrenew)

NAME	UNITS	DEFINITION
WPETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	$87/bbl	Ethanol price/step
WQETOH(MNCROP,MNUMCR,MNUMYR,MNETOH)	Mbbl/cd	Ethanol quan/step
PBMET(MNUMCR,MNUMYR)	$87/MMBTU	Ethanol price
QBMET(MNUMCR,MNUMYR)	Mbbl/cd	Ethanol quantity
WQTOT(MNUMCR,MNETOH)	Mbbl/cd	Incremental ethanol quantity

ECONOMIC VARIABLES (macout)

NAME	UNITS	DEFINITION
MC_PCWGDP(-2,MNUMYR)	Index	Implicit GDP price deflator, Ch-weighted

COAL VARIABLES (coalout)

NAME	UNITS	DEFINITION
LCVELAS(MNUMPR,MNUMYR)	---	Elasticity for CTL coal supply curve
LCVTONQ(MNUMPR,MNUMYR)	MMton/yr	CTL coal supply curve production
LCVTONP(MNUMPR,MNUMYR)	87$/ton	CTL coal supply curve delivered price
LCVBTU(MNUMPR,MNUMYR)	MMbtu/ton	CTL coal supply curve heat content
LTRNTON(MNUMPR,MNUMYR)	87$/ton	Coal transportation rate to CTL facility

A.1.4 Other PMM Variables

VARIABLES USED INTERNALLY IN PMM (pmmcom1)

NAME	UNITS	DEFINITION
PMM parameters		
PUNITSN	= 82	Number of refinery processing units
CTL_NLIQ	= 10	Max number of liquid streams out of CTL
Refinery products prices		
PAS(MNUMCR,MNUMYR)	$87/bbl	Asphalt and road oil
PDSC(MNUMCR,MNUMYR)	$87/bbl	Avg pr btwn DSU and DSL
PDSLTR(MNUMCR,MNUMYR)	$87/bbl	Low sulfur diesel (DSL), tran price
PDSU(MNUMCR,MNUMYR)	$87/bbl	Ultra low sulfur diesel (DSU)
PDSUTR(MNUMCR,MNUMYR)	$87/bbl	Ultra low sulfur diesel (DSU), tran price
PE85(MNUMCR,MNUMYR)	$87/bbl	E85
PKS(MNUMCR,MNUMYR)	$87/bbl	Kerosene
PLG(MNUMCR,MNUMYR)	$87/bbl	LPG
PM85(MNUMCR,MNUMYR)	$87/bbl	M85
PMG2TR(MNUMCR,MNUMYR)	$87/bbl	TRG mogas with markup
PMG3TR(MNUMCR,MNUMYR)	$87/bbl	RFG mogas with markup
PMG4TR(MNUMCR,MNUMYR)	$87/bbl	TRH mogas with markup
PMG5TR(MNUMCR,MNUMYR)	$87/bbl	RFH mogas with mu
PMGRFG(MNUMCR,MNUMYR)	$87/bbl	RFG mogas
PMGRFH(MNUMCR,MNUMYR)	$87/bbl	RFH mogas
PMGTRG(MNUMCR,MNUMYR)	$87/bbl	Conventional mogas
PMGTRH(MNUMCR,MNUMYR)	$87/bbl	TRH mogas
POTH(MNUMCR,MNUMYR)	$87/bbl	Other
PPC(MNUMCR,MNUMYR)	$87/bbl	Petroleum coke
PPF(MNUMCR,MNUMYR)	$87/bbl	Petrochemical feedstocks
PRH(MNUMCR,MNUMYR)	$87/bbl	High sulfur resid.
PRHUT(MNUMCR,MNUMYR)	$87/bbl	High sulfur utiltiy resid.

NAME	UNITS	DEFINITION
PRL(MNUMCR,MNUMYR)	$87/bbl	Residual fuel oil low sulfur
PRLUT(MNUMCR,MNUMYR)	$87/bbl	Low sulfur utility resid.
	Refinery fuel use	
QCDUPD(MNUMYR)	MMbbl/cd	Fuel burned (including pet coke)
QCOKFU(MNUMPR,MNUMYR)	Mbbl/cd	Petroleum coke
QCOLFU(MNUMPR,MNUMYR)	Mbbl/cd	Coal
QDISFU(MNUMPR,MNUMYR)	Mbbl/cd	Distillate
QLPGFU(MNUMPR,MNUMYR)	Mbbl/cd	LPG
QNTGFU(MNUMPR,MNUMYR)	Mbbl/cd	Natural gas
QOTHFU(MNUMPR,MNUMYR)	Mbbl/cd	Other
QRESFU(MNUMPR,MNUMYR)	Mbbl/cd	Resid.
QSTGFU(MNUMPR,MNUMYR)	Mbbl/cd	Still gas
	End use markups by sector	
ASMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Asphalt and road oil
DSMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Distillate
DSMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
DSMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
ETMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	E85
ETSTTX(MNUMCR)	$87/MMBtu	Same as ETMUTR above
KSMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Kerosene
KSMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
KSMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
KSMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	LPG
LGMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
LGSTTX(MNUMCR)	$87/MMBtu	Same as LGMUTR above
MEMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	M85
MESTTX(MNUMCR)	$87/MMBtu	Same as MEMUTR above
MGMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Motor gasoline mark ups All Sectors
MGMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	Commercial
MGMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Industrial
OTMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Other
OTMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Other markups industrial sector
OTMURS(MNUMCR,MNUMYR,2)	$87/MMBtu	
OTMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	Other markups transportation sector
PFMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	Petrochemical feedstocks
RFBMAST(MNUMCR)	$87/bbl	AST benchmarking factor
RFBMCOK(MNUMCR)	$87/bbl	COK benchmarking factor
RFBMDSL(MNUMCR)	$87/bbl	DSL benchmarking factor
RFBMDSU(MNUMCR)	$87/bbl	DSU benchmarking factor
RFBME85(MNUMCR)	$87/bbl	E85 benchmarking factor
RFBMJTA(MNUMCR)	$87/bbl	JTA benchmarking factor
RFBMKER(MNUMCR)	$87/bbl	KER benchmarking factor
RFBMLPG(MNUMCR)	$87/bbl	LPG benchmarking factor
RFBMM85(MNUMCR)	$87/bbl	M85 benchmarking factor
RFBMN2H(MNUMCR)	$87/bbl	N2H benchmarking factor
RFBMN67(MNUMCR)	$87/bbl	N67 benchmarking factor
RFBMN68(MNUMCR)	$87/bbl	N68 benchmarking factor

NAME	UNITS	DEFINITION
RFBMN6B(MNUMCR)	$87/bbl	N6B benchmarking factor
RFBMN6I(MNUMCR)	$87/bbl	N6I benchmarking factor
RFBMOTH(MNUMCR)	$87/bbl	OTH benchmarking factor
RFBMPCF(MNUMCR)	$87/bbl	PCF benchmarking factor
RFBMRFG(MNUMCR)	$87/bbl	RFG benchmarking factor
RFBMRFH(MNUMCR)	$87/bbl	RFH benchmarking factor
RFBMTRG(MNUMCR)	$87/bbl	TRG benchmarking factor
RFBMTRH(MNUMCR)	$87/bbl	TRH benchmarking factor
RHMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	High Sulfur Resid.
RHMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
RHMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
RHSTTX(MNUMCR)	$87/MMBtu	Same as RHMUTR above
RLMUAS(MNUMCR,MNUMYR,2)	$87/MMBtu	Low sulfur Resid.
RLMUCM(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUEL(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUIN(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLMUTR(MNUMCR,MNUMYR,2)	$87/MMBtu	
RLSTTX(MNUMCR)	$87/MMBtu	Same as RLMUTR above
	Delivered petroleum product prices	
RFDLAST(MNUMCR,MNUMYR)	$87/bbl	AST
RFDLCOK(MNUMCR,MNUMYR)	$87/bbl	COK
RFDLDSL(MNUMCR,MNUMYR)	$87/bbl	DSL
RFDLDSU(MNUMCR,MNUMYR)	$87/bbl	DSU
RFDLE85(MNUMCR,MNUMYR)	$87/bbl	E85
RFDLJTA(MNUMCR,MNUMYR)	$87/bbl	JTA
RFDLKER(MNUMCR,MNUMYR)	$87/bbl	KER
RFDLLPG(MNUMCR,MNUMYR)	$87/bbl	LPG
RFDLM85(MNUMCR,MNUMYR)	$87/bbl	M85
RFDLMG(MNUMCR,MNUMYR)	$87/bbl	Motor gasoline
RFDLN2H(MNUMCR,MNUMYR)	$87/bbl	N2H
RFDLN67(MNUMCR,MNUMYR)	$87/bbl	N67
RFDLN68(MNUMCR,MNUMYR)	$87/bbl	N68
RFDLN6B(MNUMCR,MNUMYR)	$87/bbl	N6B
RFDLN6I(MNUMCR,MNUMYR)	$87/bbl	N6I
RFDLOTH(MNUMCR,MNUMYR)	$87/bbl	OTH
RFDLPCF(MNUMCR,MNUMYR)	$87/bbl	PCF
RFDLRFG(MNUMCR,MNUMYR)	$87/bbl	RFG
RFDLRFH(MNUMCR,MNUMYR)	$87/bbl	RFH
RFDLTRG(MNUMCR,MNUMYR)	$87/bbl	TRG
RFDLTRH(MNUMCR,MNUMYR)	$87/bbl	TRH
	Refinery Gate product prices	
RFGTAST(MNUMPR+1,MNUMYR)	$87/bbl	AST
RFGTCOK(MNUMPR+1,MNUMYR)	$87/bbl	COK
RFGTDSL(MNUMPR+1,MNUMYR)	$87/bbl	DSL
RFGTDSU(MNUMPR+1,MNUMYR)	$87/bbl	DSU
RFGTJTA(MNUMPR+1,MNUMYR)	$87/bbl	JTA
RFGTKER(MNUMPR+1,MNUMYR)	$87/bbl	KER
RFGTLPG(MNUMPR+1,MNUMYR)	$87/bbl	LPG
RFGTMG(MNUMPR+1,MNUMYR)	$87/bbl	Motor gasoline
RFGTN2H(MNUMPR+1,MNUMYR)	$87/bbl	N2H
RFGTN6B(MNUMPR+1,MNUMYR)	$87/bbl	N6B
RFGTN6I(MNUMPR+1,MNUMYR)	$87/bbl	N6I
RFGTOTH(MNUMPR+1,MNUMYR)	$87/bbl	OTH
RFGTPCF(MNUMPR+1,MNUMYR)	$87/bbl	PCF

NAME	UNITS	DEFINITION
RFGTRFG(MNUMPR+1,MNUMYR)	$87/bbl	RFG
RFGTRFH(MNUMPR+1,MNUMYR)	$87/bbl	RFH
RFGTTRG(MNUMPR+1,MNUMYR)	$87/bbl	TRG
RFGTTRH(MNUMPR+1,MNUMYR)	$87/bbl	TRH
	Crude Variables	
CRDOTHTOT(MNUMPR,MNUMYR)	MMbbl/cd	Total other crude suplied
CRDPRDSUP(MNUMPR,MNUMYR)	MMbbl/cd	Crude product withdrawals
CRDSTWDR(MNUMPR,MNUMYR)	MMbbl/cd	Crude stock withdrawals
CRDUNACC(MNUNPR,MNUMYR)	MMbbl/cd	Unnaccouted crude
FHLADD(MNUMPR)	Mbbl/cd	Additonal supply imports of HL crude
OLEOYRS(MNUMOR,MNUMYR)	MMbbl	End of year reserves for oil
OLEXTRT(MNUMOR,MNUMYR)	MMbbl/day/MMbbl	Production Ratio
OLPELC(MNUMOR)	Dimensionless	Price elasticity beta
OLWHP(MNUMOR)	$87/bbl	Well head price for (year - 1)
OLALP(MNUMOR)	Dimensionless	Well head price alpha
OLBTA(MNUMOR)	Dimensionless	Well head price beta
PCRDRF(MNUMPR,MNUMYR,5,3)	$87/bbl	Price of crude, refinery gate
PICRD(MNUMYR,3,5,3)	87$/bbl	Price of imported crude
PQEXCRDIN(MNUMPR,MNUMYR)	Mbbl/cd	Exported crude except Alaskan
PQUFC1(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 1
PQUFC2(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 2
PQUFC3(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 3
PQUFC4(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 4
PQUFC5(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 5
PQUFC6(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 6
PQUFC7(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 7
PQUFC8(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 8
PQUFC9(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 9
PQUFC10(MNUMPR,MNUMYR,2)	$87/bbl,Mbbl/cd	Unfinished crude 10
QCRDRF(MNUMPR,MNUMYR,6,4)	Mbbl/cd	Quantity of crude, refinery gate
QICRD(MNUMYR,3,5,3)	Mbbl	Imported crude
RFCRDDCR(MNUMYR)	Mbbl/cd	Domestic crude production
RFCRDAKA(MNUMYR)	Mbbl/cd	Alaskan crude production
RFCRDL48(MNUMYR)	Mbbl/cd	Lower 48 crude production
RFCRDTOT(MNUMYR)	MMbbl/cd	Total crude production
WLLHDPR(MNUMOR,MNUMYR)	$1987/Bbl	Domestic crude well head price
XRFWOP(MNUMYR,2)	MMbbl/cd	Local expected WOP
	Investment Variables	
BLDYRS	yrs	Construction period for proc units
BM_ISBL	$M	B&M ISBL (convert fr 93$ to 87$ in code)
BM_LABOR	$/cd	B&M Labor (convert fr 93$ to 87$ in code)
CAPREC	$87/bbl/cd	Capital recovery
CAPRECSW	integer	Capital recovery switch for investment
CUMINSTRF(MNUMPR,PUNITSN+1,MNUMYR)	$MM	Total refinery investment
ENV_FAC	percentage	Yearly environ, % of P&E
FTAXRAT	fraction	FED income tax rate
FXOC	$87/bbl	Fixed operating costs
INFLRAT	fraction	Inflation rate
INS_FAC	percentage	Yearly insurance, % of P&E
INV	$87/bbl/cd	Proc unit investment
INVENV	--	Environment invst cost factor
INVLOC	--	Location invst penalty factor
INVST0_FIN	$87/bbl/cd	Final investment
MAINT_FAC	percentage	Yearly maintenance, % of P&E

NAME	UNITS	DEFINITION
OH_FAC	percentage	Yearly overhead, % of P&E
PCTCNTG	percentage	Contingency
PCTENV	percentage	ENV: % of core P&E
PCTLND	percentage	LAND cost: % of core P&E
PCTOFS	percentage	OFFSITES: % of core P&E
PCTLOC	percentage	Location factor
PCTUTL	percentage	UTIL cost: % of core P&E
PCTSPECL	percentage	Special costs
PCTWC	percentage	Working capital
PRJLIFE	yrs	Project life for proc units
PUCAP	Mbbl/cd	Proc unit capacity used for investment
RQBLDRAT	fraction	Req. recovery rate for builds
RQOPRRAT	fraction	Req. recovery rate for operation
RQRECRAT	fraction	Req. recovery rate
STAXRAT	fraction	ST income tax rate
SUP_FAC	percentage	Yearly supplies, % of P&E
TAX_FAC	percentage	Local tax rate, % of P&E
Technology Improvement Variables		
TYR1	year	1st yr of tech change phase-in--GLOBAL
TYR2	year	Last yr of tech change phase-in--GLOBAL
UYR1(50)	year	1st yr of tech change phase-in--PROC UNIT
UYR2(50)	year	Last year of tech change phase-in-PROCUNIT
UTCHCNT	text	Num of proc units w/ tech chng defined
PCT_CHNG(MNUMYR)	fraction	% chng off base coef due to tech--GLOBAL
UPCT_CHNG(50,MNUMYR)	fraction	% chng off base coef due to tech--PROCUNIT
PUNIT	integer	# of proc units with tech imporvements
UNAMID(50)	text	Proc unit name
GLOBTECH	--	Flag to perform tech chng GLOBALLY
UNITTECH	--	Flag to perform tech chng for PROC UNIT
YLDUNIT(10)	text	Proc unit name for yield improvement
YLDYR(10)	integer	Start year for yield improvement
MNAMID(50)	text	Proc unit mode name
PMODE(10)	integer	# of proc unit modes for yield improvement
YLDMODE(10,10)	text	Proc unit mode ID for yield improvement
PSTRM(10,10)	integer	# of stream for yield improvement
YLDSTRM(10,10,11)	text	Stream ID for yield improvement
CHNGYLD(10,10,10)	real	New yield coeff for yield improvement
FLGGRX(50)	integer	Flag for gravity spec improvement
FLGSLX(50)	integer	Flag for sulfur spec improvement
SPCYR(50)	integer	Year for spec improvement
SSPEC(50)	integer	# of strm specs for spec improvement
SSPECID(50,10)	text	Stream spec ID for spec improvement
SSTRM	integer	# of strm for speck improvement
SSTRMID(50)	text	Stream ID for speck improvement
CHNGSPC(50,10)	real	New yield coeff for spec improvement
Coal to Liquids (CTL) Variables		
CTL_DCLCAPCST	fraction	Annual decline rate for cap rec due to imprv tech
CTL_DCLOPRCST	fraction	Annual decline rate for opr cost due to imprv tech
CTL_BASHHV	MMbtu/ton	Coal HHV
CTL_BASSIZ	Mbbl/cd (liq out)	Base size for CTL unit
CTL_BASCOL	M ton/cd (coal)	Base level coal consumption for CTL
CTL_BASCGS	MW	Base cogen for self consumption (from CTL)
CTL_BASCGG	MW	Base cogen sold to grid (from CTL)
CTL_BASCGF	fraction	Cogen capacity factor (from CTL)

NAME	UNITS	DEFINITION
CTL_CO2FAC(MNUMPR,MNUMYR)	ratio	Lbs CO2 emiss per bbl CTL liq produced
CTL_CGTFAC(MNUMPR,MNUMYR)	ratio	Tot kWh elec cogen per bbl CTL liq produced
CTL_CGGFAC(MNUMPR,MNUMYR)	ratio	KWh elec cogen to grid per bbl CTL liq produced
CTL_CSTFAC(MNUMPR)	factor	Cap/op cost factor for CTL processing unit costs
CTL_INCBLD	M bbl/cd	iIcremental build size for CTL processing units
P_CTLTRN(CTL_NLIQ,MNUMPR,MNUMYR)	87$/bbl	Cost to transfer CTL to refinery
P_CTLINV(MNUMPR,MNUMYR)	MM $87/yr	Investment cost for CTL builds/production
Q_CTLPRD(MNUMPR,MNUMYR)	M bbl/cd	Quantity of liquids produced from coal via CTL
CTL_CGCTOT(MNUMPR,MNUMYR)	MW	Total cogen capacity from CTL processing
CTL_CGCGD(MNUMPR,MNUMYR)	MW	Cogen capacity from CTL, to grid
CTL_CGCSF(MNUMPR,MNUMYR)	MW	Cogen capacity from CTL, to self
CTL_CGGTOT(MNUMPR,MNUMYR)	MWh/cd	Total cogen elec gen from CTL processing
CTL_CGGGD(MNUMPR,MNUMYR)	MWh/cd	Cogen elec gen from CTL, to grid
CTL_CGGSF(MNUMPR,MNUMYR)	MWh/cd	Cogen elec gen from CTL, to self
CTL_CO2EM(MNUMPR,MNUMYR)	M lbs/cd	CO2 emissions from CTL processing
CTLMINP(MNUMPR,MNUMYR)	87$/ton	Minemouth price of coal for CTL
P_CTLCOAL(MNUMPR,MNUMYR)	87$/ton	Price of coal used for CTL
Q_CTLCOAL(MNUMPR,MNUMYR)	M ton/cd	Quantity of coal used for CTL
XLCVELAS(MNUMPR,MNUMYR)	---	Elasticity for CTL coal supply curve
XLCVTONQ(MNUMPR,MNUMYR)	MMton/yr	CTL coal supply curve production
XLCVTONP(MNUMPR,MNUMYR)	87$/ton	CTL coal supply curve delivered price
XLCVBTU(MNUMPR,MNUMYR)	MMbtu/ton	CTL coal supply curve heat content
XLTRNTON(MNUMPR,MNUMYR)	87$/ton	Coal transportation rate to CTL facility
CTL_PLNBLD(MNUMPR,MNUMYR)	M bbl/cd	Max CTL build capacity
CTLBLDX	#	Max number of CTL units allowed
IINDX	index	Mansfield-Blackman innovation index
PINDX	index	Mansfield-Blackman relative profitability index
SINVST	index	Mansfield-Blackman relative investment size
RFCTLLIQ(CTL_NLIQ)	M bbl/cd	CTL production, by liq type
CTL_INVCST	87$/bbl	CTL investment
CTLTAXCR(MNUMYR)	nom$/bbl	CTL tax credit
CTL_NAM(MNUMPR)	char*4	Coal ID + PADD (1-3,4)
CTL_LIQNAM(CTL_NLIQ)	char*3	CTL liquid stream ID (1-3)
CTL_NCL	integer	Number of coal types for CTL processing
CTL_LIQNCL	integer	Number of CTL liquid stream types

Renewables in Fuel Variables

STMTBVAL(MNUMCR)	fraction	Fraction of product demand for state MTBE ban
MINREN(MNUMYR)	Bil gal/yr	Minimum renewables in total gasoline & diesel
REN_RAT	fraction	Min frac of renewables in total gasoline & diesel
BIMSUP(MNUMYR)	Bil gal/yr	Quantity of Biomass diesel required as product
ISOCVRTN	fraction	Min frac for convers. of MTBE units to ISO-units
ISOCVRTX	fraction	Max frac for conversion of MTBE unit to ISO-units
RENETHPR(MNUMCR,MNUMYR)	87$/bbl	Base ethanol price before adj due to renew min req
RENADJPR(MNUMCR,MNUMYR)	87$/bbl	Price adj for rfg,rfh due to renew min requirement

Miscellaneous Variables

ALFA	fraction	Weight for industrial electricity purchase
ALKACT(MNUMPR,MNUMYR,9)	Mbbl/cd	Alkylation unit activity variable by mode
ALKMOD(9)	Text	Alkylation unit mode
ARG(MNUMCR,MNUMYR)	real	Coeff in ethanol equation (tech dependent)
BLDETHRF(MNUMPR,MNUMYR)	Mbbl/cd	Ethanol blended at refinery
BLDPRD(MNUMPR,MNUMYR)	MMbbl/cd	Product blending component
BLDSPLT(MNUMYR,PUNITSN,MNUMYR+3)	Percent	Build splits for specific units (data)
CAPCRD(MNUMYR,14)	Percent	Crude pipeline utilization

NAME	UNITS	DEFINITION
CAPCSTCL(MNUMYR)	87$	Capital costs for Biomass conversion
CAPEXPFCT(5,60,MNUMYR)	Percent	Processing unit capacity expansions factor
CAPGTLNS(MNUMYR)	Mbbl/cd	Total GTL capacity
CAPLPG(MNUMYR,10)	Percent	LPG pipeline utilization
CAPPRD(MNUMYR,21)	Pecerent	Product pipeline utilization
CD2CD_CB(2,100)	Integer	CD To CD Via Clean Barge
CD2CD_CT(2,100)	Integer	CD To CD Via Clean Tanker
CD2CD_DB(2,100)	Integer	CD To CD Via Dirty Barge
CD2CD_DT(2,100)	Integer	CD To CD Via Dirty Tanker
CD2CD_ECB(2,100)	Integer	CD To CD Via Clean Barge (Eth)
CD2CD_EDB(2,100)	Integer	CD To CD Via Dirty Barge (Eth)
CD2CD_LT(2,100)	Integer	CD To CD Via Tanker (Lpg)
CFDLQ	MMbtu/bbl	BTU content of DSL (low sulfur diesel)
CFDSAVG(MNUMYR)	MMbtu/bbl	Avg BTU content for DSU & DSL
CFDUQ	MMbtu/bbl	BTU content of DSU (ultra low sulfur diesel)
CFDUQLOS	Percent	% loss of BTU content (fr DSL to DSU)
CFNHQ	MMbtu/bbl	BTU content of N2H (heating oil)
CHG_BLDSPLT(PUNITSN)	Integer	Flag to change build splits (0=no, 1=yes)
CLLCAPCD(MNUMCR,MNUMYR)	Mbbl/d	Biomass capacity--cellulose
CLLCSTCD(MNUMCR,MNUMYR)	$/bbl	Biomass cost--cellulose
CONEFF(MNUMYR)	fraction	Biomass conversion efficiency
CRNCSTCD(MNUMCR,MNUMYR)	$/bbl	Biomass cost—corn
DEF_BLDSPLT(MNUMPR,3)	Percent	Build splits for specific units (data)
DMDHDSL(MNUMCR,MNUMYR)	Mbbl/cd	Dmd for highway DSL, by CD
DMDHDSU(MNUMCR,MNUMYR)	Mbbl/cd	Dmd for highway DSU, by CD
DMDN2H(MNUMCR,MNUMYR)	Mbbl/cd	Dmd for distillate, by CD
DMDODSL(MNUMCR,MNUMYR)	Mbbl/cd	Dmd for non-highway DSL, by CD
DSLCHAR(40)	Character	Distillate/spec variable ID
DSLIND	Percent	Low sulfur diesel and distillate split (indus)
DSLTRN	Percent	Split btwn highway and offroad diesel dmd (trans)
DSSPCS(40,MNUMYR)	??/bbl	Spec requirement for distillates
DSUPCT(MNUMYR)	Percent	Percent DSU of total diesel demand
E85TXPCT	fraction	E85 component of cellulose subsidy
ETH4ETHR(MNUMPR,MNUMYR)	Mbbl/cd	Ethanol used to produce ethers
ETHE85CD(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used for E85 production
ETHPRIC(2,MNUMYR)	$87/bbl	Cost coef for ETH, E85
ETHR_O2(7)	fraction	Wt. Fraction O2 in ethers/ETH
ETHR_SG	--	Specific gravity of ethers/ETH
ETHSUB(MNUMYR)	$/bbl	Ethanol subsidy
ETHTOTCD(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used
ETHTOTPR(MNUMCR,MNUMYR)		Total ethanol production - corn + cellulose
EXPMAX(11,5)	Mbbl/cd	Maximum product export quantity
EXPMIN(11,5)	Mbbl/cd	Minimum product export quantity
EXPRAT	--	Product export ratio used in regression
EXPRD(11)	text	List of product exports
EXPRDDMD(11,5)	Mbbl/cd	Prod dmd grouped by exort reg for exp prod only
FCCACT(MNUMPR,MNUMYR,116)	Mbbl/cd	FCC unit activity variable by mode
FCCDUAL(MNUMPR,MNUMYR,116)	$87/bbl	RFG specification row dual activity
FCCMOD(116)	Text	FCC unit modes
FLOWCD_CB(MNUMYR,100)	Mbblcd	Flow From CD To CD Via Clean Barge
FLOWCD_CT(MNUMYR,100)	Mbblcd	Flow From CD To CD Via Clean Tanker
FLOWCD_DB(MNUMYR,100)	Mbblcd	Flow From CD To CD Via Dirty Barge
FLOWCD_DT(MNUMYR,100)	Mbblcd	Flow From CD To CD Via Dirty Tanker
FLOWCD_ECB(MNUMYR,100)	Mbblcd	Eth Flow From CD To CD Via Clean Barge
FLOWCD_EDB(MNUMYR,100)	Mbblcd	Eth Flow From CD To CD Via Dirty Barge
FLOWCD_LT(MNUMYR,100)	Mbblcd	Lpg Flow From CD To CD Via Tanker
FLOWCRD(MNUMYR,14)	Mbbl/cd	Crude pipeline flow

NAME	UNITS	DEFINITION
FLOWLPG(MNUMYR,10)	Mbbl/cd	LPG pipeline flow
FLOWPD_CB(MNUMYR,100)	Mbblcd	Flow From PADD To CD Via Clean Barge
FLOWPD_CT(MNUMYR,100)	Mbblcd	Flow From PADD To CD Via Clean Tanker
FLOWPD_DB(MNUMYR,100)	Mbblcd	Flow From PADD To CD Via Dirty Barge
FLOWPD_DT(MNUMYR,100)	Mbblcd	Flow From PADD To CD Via Dirty Tanker
FLOWPD_ECB(MNUMYR,100)	Mbblcd	Eth Flow From PADDo CD Via Clean Barge
FLOWPD_EDB(MNUMYR,100)	Mbblcd	Eth Flow From PADDo CD Via Dirty Barge
FLOWPD_LT(MNUMYR,100)	Mbblcd	Lpg Flow From PADD To CD Via Tanker
FLOWPRD(MNUMYR,21)	Mbbl/cd	Product pipeline flow
FSCSTCL(MNUMCR,MNUMYR)	87$	Costs
GPRDIMP(3,14)	fraction	Growth rate for product imports
GTL_INCBLD	Mbbl/cd	Incremental build level allowed for GTL units
HH2_CONS(MNUMPR,PUNITSN+1,MNUMYR)	Mbbl(foe)/cd	Hydrogen consumption, by reg, unit, yr
HH2_FUXC(MNUMPR,MNUMYR)	Mbbl(foe)/cd	Hydrogen consumed by FUX
HH2_FUXP(MNUMPR,MNUMYR)	Mbbl(foe)/cd	Hydrogen produced by other units
HH2_FUXUC(MNUMPR)	Integer	Flag indicating H2 consumed by FUX in region
HH2_FUXUP(MNUMPR)	Integer	Flag indicating H2 produced by FUX in region
HH2_PROD(MNUMPR,PUNITSN+1,MNUMYR)	Mbbl(foe)/cd	Hydrogen produced, by reg, unit, yr
HH2_UNITC(MNUMPR,PUNITSN)	Integer	Flag indicating units consuming H2 in region
HH2_UNITP(MNUMPR,PUNITSN)	Integer	Flag indicating units producing H2 in region
IRACBND(2)	$87/bbl	IRAC bounds
IRACN	$87/bbl	Refiner acquisition cost min. tolerance
IRACX	$87/bbl	Refiner acquisition cost max. tolerance
N6XPRC(9)	Fraction	Price step adjustment for N6I/B
N6XQNT(9)	Fraction	Supply step adjustment for N6I/B
LLPRDEXP(11,5,MNUMYR)	Mbbl/cd	Lower bound on prod exports (for cap expan)
LOWBND	None	Variable for passing data to OML
MARKET((MNUMCR,MNUMYR)	real	Factor in ethanol equation
MGSBCHAR(5,11)	text	Gasoline blend category for SSR, SST, RFH, TRH, SSE (TYP,BLND)
MGSBLND(5,5,11,5)		Gasoline blend specs for SSR, SST, RFH, TRH, SSE (PADD,TYP,BLND,YR)
MGSPCS(80,MNUMYR)	Many	Motor gasoline specifications
MGSHR(MNUMYR,6,MNUMCR)	Percent	Motor gasoline market shares
MISCINP(MNUMPR,MNUMYR)	MMbbl/cd	Miscellaneous inputs
MOGAS_O2N	fraction	Wt. Fraction O2 in mogas
MOGAS_SG	--	Specific gravity of mogas
MTBERFGX	Wt. Fraction	Max oxygenate in RFG allowed to be MTBE
MTBETRGX	Wt. Fraction	Max oxygenate in TRG allowed to be MTBE
NGLMK(MNUMPR,MNUMYR,6,2)	MMbbl/cd	NGL to market
NGLRF(MNUMPR,MNUMYR,6,2)	MMbbl/cd	NGL from refinery
NGRFUPIT(MNUMPR)	MMbbl/cd	Natural gas fuel use previous iteration
OPCSTCL(MNUMYR)	87$	Operating costs for Biomass conversion
OTHOXY(MNUMPR,MNUMYR)	MMbbl/cd	Other oxgenates
P2HL(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream 2HL
PADD2CD_CB(2,100)	Integer	PADD To CD Via Clean Barge
PADD2CD_CT(2,100)	Integer	PADD To CD Via Clean Tanker
PADD2CD_DB(2,100)	Integer	PADD To CD Via Dirty Barge
PADD2CD_DT(2,100)	Integer	PADD To CD Via Dirty Tanker
PADD2CD_ECB(2,100)	Integer	PADD To CD Via Clean Barge (Eth)
PADD2CD_EDB(2,100)	Integer	PADD To CD Via Dirty Barge (Eth)
PADD2CD_LT(2,100)	Integer	PADD To CD Via Tanker (Lpg)
PALB(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream ALB
PCOKH	None	Variable for passing data to OML
PCOKL	None	Variable for passing data to OML
PCT_DWNGRD(MNUMYR)	Percent	Percent of DSU downgraded at CD due to transp

NAME	UNITS	DEFINITION
PCTCARB	fraction	Projected 2010 carbon emissions relative to 1990
PETB(MNUMPR, MNUMYR)	$87/bbl	Price of ETBE
PETHANOL(MNUMCR,MNUMYR)	87$/bbl	Marginal cost for ethanol
PETHRFBL(MNUMPR,MNUMYR)	$87/bbl	Refinery ethanol blending cost
PEXPDS(MNUMCR,MNUMYR)	Mbbl/cd	DSL exports, by CD
PFC8(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream FC8
PGPLTRF(MNUMPR,MNUMYR,18)	$87/bbl	Refinery production costs
PKHL(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream KHL
PMETRFBL(MNUMPR,MNUMYR)	$87/bbl	Refinery methanol blending cost
PMMCAPI(MNUMPR,PUNITSN)	Mbbl/cd	Initial refinery unit capacity
PMMOBJ(MNUMYR)	M$87/day	Objective function value by year
PMTB25(MNUMPR, MNUMYR)	$87/bbl	Price of MTBE
PMMTRFBL(MNUMPR,MNUMYR)	$87/bbl	Refinery MTBE blending cost
PR10(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream R10
PRDDMD(MNUMCR,MNUMYR,30)	Mbbl/cd	Product demand
PRDDMDME(MNUMYR)	Mbbl/cd	Chemical methanol demand
PRDEXPTOT(MNUMYR)	MMbbl/cd	Total allowable product exports
PRDSTKWDR(MNUMPR,MNUMYR)	MMbbl/cd	Product stocks withdrawals
PRDTOT(MNUMYR)	Mbbl/cd	Total product demand for report 4
PRFELPURPD(MNUMPR,MNUMYR)	$87/kWh	Refinery electricity costs
PRFNGFU(MNUMPR,MNUMYR)	$87/bbl (foe)	Refinery NG fuel cost
PRHEQ(MNUMCR,MNUMYR)	Cents/gal	High sulfur resid (eq price)
PRHUTEQ(MNUMCR,MNUMYR)	Cents/gal	High sulfur util. resid (eq price)
PRICLP	None	Variable for passing data to OML
PRLEQ(MNUMCR,MNUMYR)	Cents/gal	Low sulfur resid (eq price)
PRLUTEQ(MNUMCR,MNUMYR)	Cents/gal	Low sulfur util. resid (eq price)
PRPFF(5)	MFOEbbl/day	RHS value for resid. by PAD District
PRPFU(5)	MFOEbbl/day	RHS value for resid. by PAD District
PSRI(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream SRI
PSULSAL(MNUMPR)	$87/s ton	Price of saleable sulfur
PTAE(MNUMPR, MNUMYR)	$87/bbl	Price of TAEE
PTAM(MNUMPR, MNUMYR)	$87/bbl	Price of TAME
PTHE(MNUMPR, MNUMYR)	$87/bbl	Price of THEE
PTHM(MNUMPR, MNUMYR)	$87/bbl	Price of THME
PUBASE(MNUMPR,60,MNUMYR)	Mbbl/cd	Processing units base capacity
PUBASEUT(MNUMPR,60,MNUMYR)	Pecent	Processing units base utilization
PUCUM(MNUMPR,60,MNUMYR+4)	Mbbl/cd	Process unit cumulative builds
PUINV(MNUMPR,60,MNUMYR+4)	Mbbl/cd	Process unit investment builds
PWCRDCL(MNUMYR)	87$	Costs for Biomass conversion
PVAF(MNUMPR, MNUMYR)	$87/bbl	Marg pr for stream VAF
Q_GTLPRD(MNUMPR,MNUMYR)	M bbl/cd	Quantity of liquids produced from GTL processing
Q_GTLGAS(MNUMPR,MNUMYR)	BCF/cd	Quantity of NG consumed for GTL processing
QETHRFN(MNUMPR,MNUMYR)	Mbbl/cd	Refinery ethanol blending volume
QGPLTRF(MNUMPR,MNUMYR,18)	BCF	Refinery gas plant production volumes
QMETRFN(MNUMPR,MNUMYR)	Mbbl/cd	Refinery methanol blending volume
QPRDEX(MNUMCR,30,MNUMYR)	Mbbl/cd	Refinery production export by product
QPRDEXD(MNUMPR,30,MNUMYR)	Mbbl/cd	Production distress export by product
QPRDIMD(MNUMCR,30,MNUMYR)	Mbbl/cd	Quantity of total distress product imports
QPRDIMP(MNUMYR,3,14,3)	Mbbl/d	Product imports
QPRDRF(MNUMPR,MNUMYR,30)	Mbbl/cd	Refinery production volume by product
QPRDRFT(MNUMYR)	Mbbl/cd	Total refinery production volumes
QRFMPMT(MNUMPR,MNUMYR)	Mbbl/cd	Methanol qty transferred fr refinery to merchant
QSUBFU(MNUMPR,MNUMYR)	MMbbl/cd	Subtotal refinery fuel use w/o nat. gas
QSULSAL(MNUMPR)	1000 s ton/ yr	Quantity of saleable sulfur produced
QTOTFU(MNUMPR,MNUMYR)	MMbbl/cd	Total refinery fuel use with natural gas
RETHRIMP(MNUMPR,MNUMYR)	Mbbl/cd	Imported ethers

NAME	UNITS	DEFINITION
RFCAPREC(3,60,MNUMYR)	$/bbl	Refinery processing unit capital recovery factor
RFCGCONS(MNUMPR,MNUMYR)	tBtu	Refinery cogeneration PAD District
RFCGFUELCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Fuel by cenus division
RFCGFUELPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. Fuel
RFCGGENCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Generation
RFCGGENPD(MNUMPR,MNUMYR)	TBtu	Refinery cogeneation by PAD Ditrict
RFCGGRIDCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. To grid by cenus division
RFCGGRIDPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. to grid by PAD District
RFCGREC(MNUMPR,MNUMYR)	kWh	Receipts of electricity
RFCGSELFCD(MNUMCR,MNUMYR)	TBtu	Refinery cogen. Self by cenus division
RFCGSELFPD(MNUMPR,MNUMYR)	TBtu	Refinery cogen. Self
RFCGSTEAM(MNUMPR,MNUMYR)	Percent	Steam, PAD District percent adjustment
RFCXCAPPD(MNUMPR,MNUMYR)	Mkw/day	Cogen capacity
RFCXGENPD(MNUMPR,MNUMYR)	Mkwh/day	Cogen generation
RFEMISST(MNUMPR,MNUMYR,12)	Many	Total refinery emissions
RFETBD(MNUMPR,MNUMYR)	MMbbl/cd	ETBE oxygenate quantity
RFETBMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant ETBE production
RFETHETB(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for ETBE
RFETHMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant ethanol consumption
RFETHMGS(MNUMPR,MNUMYR)	MMbbl/cd	Ethanol for motor gasoline
RFFMT(MNUMPR,MNUMYR,34)	Percent	Refinery fuel mix
RFFUELU(MNUMYR)	MMbbl/cd	Total refinery fuel use w/o nat. gas
RFGBCRFG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (reform. & hioxygen)
RFGBCTRG(MNUMPR,13,MNUMYR)	Mbbl/cd	Gasoline blending composition (conventional & hioxygen)
RFGSPCDL(MNUMPR,MNUMYR,9)	$87/bbl	RFG specification row dual activity
RFGSPCLM(MNUMPR,MNUMYR,9)	Text	RFG specification row status
RFGSPEC(9)	Text	RFG specifications
RFIPQDU(MNUMPR,MNUMYR,2)	MMbbl/cd,$87/bbl	Imported DSU, P/Q
RFIPQSB(MNUMPR,MNUMYR,2)	MMbbl/cd,$87/bbl	Subtotal imported product w/o Methanol
RFIPQTL(MNUMPR,MNUMYR,2)	MMbbl/cd,$87/bbl	total imported product with Methanol
RFMETETH(MNUMPR,MNUMYR)	MMbbl/cd	Methanol for ether
RFMETMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant methanol comsumption
RFMTBMCT(MNUMPR,MNUMYR)	MMbbl/cd	Merchant MTBE production
RFNGFTOT(MNUMYR)	Mbbl/cd	Total natural gas production
RFOPEXP(MNUMPR,MNUMYR)	1000 $87/cd	Refinery operating expenses
RFOTHFU(20)	text	Refinery fuel use for OTH category (3-charID)
RFPRDFX(MNUMCR,MNUMYR,24)	$87/bbl	Refinery capital cost by product
RFQNGLRF(MNUMPR,MNUMYR)	MMbbl/cd	Quantity of ngl inputs to refinery
RFSTEAM(MNUMPR,MNUMYR)	MMlb/day	Steam by PAD District
RFTAED(MNUMPR,MNUMYR)	MMbbl/cd	TAE oxygenate quantity
RFTAMD(MNUMPR,MNUMYR)	MMbbl/cd	TAME oxygenate quantity
RFTHED(MNUMPR,MNUMYR)	MMbbl/cd	THE oxygenate quantity
RFTHMD(MNUMPR,MNUMYR)	MMbbl/cd	THM oxygenate quantity
ROXYTOT(MNUMPR,MNUMYR)	MMbbl/cd	Total oxygenated volumes
RWOP(MNUMYR)	$87/bbl	PMM local expected WOP
SBG08RFG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for RFG
SBG08RFH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for RFH
SBG08TOT(MNUMCR,MNUMYR)	Mbbl/cd	Tot ethanol used for mogas blnd
SBG08TRG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for TRG
SBG08TRH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of ethanol for TRH
SBRFGRFG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of RBOB for RFG
SBRFGRFH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of RBOB for RFH
SBTRGTRG(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of SSE for TRG
SBTRGTRH(MNUMCR,MNUMYR)	Mbbl/cd	Splash blnd Vol of TBOB for TRH

NAME	UNITS	DEFINITION
SPLTTYP(PUNITSN,MNUMYR)	Integer	Represents %(=1) vs capacity(=2)
SQETOH(2,MNUMCR,MNUMYR)		Ethanol soln from cap expansion
SS_FRAC(4)	fraction	SS* fraction in RFG, RFH, TRG, TRH
STMDMD(MNUMPR,MNUMYR)	lb/bbl	Steam consumption at ref
TAP_FIXCST	1000 $87/cd	Fixed transportation cost on TAPS
TAP_MAXCAP	MMbbl/cd	Max capacity on TAPS
TAP_MINSTVOL	MMbbl/cd	Min incremental vol above MINTHRU
TAP_MINTHRU	MMbbl/cd	Min exonomic throughput on TAPS
TAP_OILADJ	Percent	Min upward adjustment on Lift Cost
TAP_OILIFT	$87/bbl	Assumed oil lifting cost in AK
TAP_VARCHG	$87/bbl	Variable trans cost on TAPS
TDIESEL(MNUMCR,MNUMYR)	Mbbl/cd	Total Highway diesel (DSU+DSL)
TOTPRD(MNUMPR,MNUMYR)	MMbbl/cd	Total refinery products sold
TRANSCL(MNUMYR)	87$	Transport costs for Biomass conversion
TRGSPCDL(MNUMPR,MNUMYR,7)	$87/bbl	RFG specification row dual activity
TRGSPCLM(MNUMPR,MNUMYR,7)	Text	TRG specification row status
TRGSPEC(7)	Text	TRG specifications
ULPRDEXP(11,5,MNUMYR)	Mbbl/cd	Upper bound on prod exports (for cap expan)
UPBND	None	Variable for passing data to OML
WOPMTPLY	Percent	Distress import price multiplier
WOPZ9EXP	Percent	Distress export price multiplier
XRFELP(MNUMCR,MNUMYR)	MMbbl/cd	Local expected electricity price
XRFNGP(MNUMCR,MNUMYR)	MMbbl/cd	Local expected natural gas price
XSTMDMD(MNUMPR,MNUMYR)	lb/bbl	Forecast steam consumption at ref (not used)
	Identifier variables	
BLDPD	Integer	Build period look-ahead (3 years)
BNDS(2)	Text	Bounds character identifiers
CAPYR1ST	Integer	First year cap expansion is run
CRDTYP(5)	Text	Crude type character identifiers
DMDRGNS	Integer	PMM demand regions index
ETHERS(7)	Text	List of ethers
FO1PMM	None	Variable for file unit identifier
FO2PMM	None	Variable for file unit identifier
IPRD(14)	Text	Imported product chrctr identifers
MG_NAM(4)	Text	Mogas types created from splash blend (SS*)
MGSCHAR(80)	Text	Mogas share character identifiers
NEMSYR1	Integer	First NEMS year (1990)
NLV(9)	Text	Census division character identifers
NLV2(9)	Text	Domestic crude supply regn identifers
QNT(9)	Text	Quantity character identifiers
PADD(5)	Text	PAD District character identifiers
PMMDBG	integer	PMM debug file unit ID
PMMRGNS	Integer	PMM refining regions index
PRCUNIT(60)	Text	Process unit character identifier
PRD(30)	Text	Product character identifiers
PRTYRS(5)	year	ID's 5 yrs to print data for MRM
RFOTHFU(20)	Text	Other fuel use character identifier
SPRPTYR$	Integer	Year $ for special tables 1a,b,c,d in pmmrpts.txt
SS_NAM(4)	Text	SS* names splash blended into 4 mogas types
SUBNM	Text	Subroutine name index
SUBNMX	Text	Passing subroutine name index
Z9EXPRD(11)	Text	Distress export index list
	Switches	
ATRHSW	integer	Switch for alternate cal of TRH price
CTL_FSTYR	year	1st year CTL allowed to be built

NAME	UNITS	DEFINITION
CTLMB_SW	integer	Switch to apply Mansfield-Blackman model
CTLTXSW	integer	Switch to apply CTL tax credit
CTLTXYR1	year	1st year to apply CTL tax credit
CTLTXYR2	year	Last year to apply CTL tax credit increment
DSUSWT	integer	Switch for DSU runs (0=base,1=side)
DSUYR1	integer	First DSU phase-in year
DSUYR2	integer	Final DSU phase-in year
EMISSCSSW	integer	Switch for emissions cost adjustment
ETHSWTX	integer	Switch for ethanol subsidy for carbon tax case
ETHTECSW	integer	Hi tech switch for ethanol, cellulose
FRSTIT	Text	Write basis on first/last iteration switch
GTL_FSTYR	integer	First possible start year for GTL builds
HISTLYR	Integer	PMM last history year
HITSWTC	text	HiTech switch
IETHHT	integer	Biomas switch for technology case
IPMM	integer	Switch for International updates (not active)
ISOFLAG	integer	flag allowing MTBE unit conversion to ISO-octane
ISOXGRNT	integer	flag for merchant ISO-octane Grant
LHCDIST(2,MNUMYR,7,30)	Percent	Model testing variable
LHCRUN	Integer	Model testing switch
MGOUTLR	integer	Switch for gasoline price outliner
MPSSWTC	Text	MPS matrix load switch
MTBEO2WV	integer	flag for mininum O2 waiver, if MTBE banned
MTBEYR	integer	First year of MTBE restriction in regions E,B
NRMSWTC	text	NRM on/off switch
ONECESW	integer	Switch for 1 cap expansion iteration
PMM_OR_MRM	Text	5 region to 3 region PMM switch
PMMBSYR	Integer	PMM base year, 1995
PMMINF	None	Infeasible solution switch
PMMSTEOBM	Text	Switch to turn on STEO benchmarking
PRCUNSWT(60)	none	Processing unit on/off switch for cap. expan.
PRDIMPSW	integer	Switch for product import calc
PRDIMPWR	integer	Switch for writing product import results
REN_YR	year	1st year for req %min renewables in gas/diesel
RENADJYR	year	1st year for adj rfg price due to renew in gas/diesel
RENITR	iteration	1st itr for adj rfg price due to renew in gas/diesel
RFADVBAS	Text	Advance basis load switch
RFAEOADJ	Text	Switch to turn on AEO adjustments
RFCESWTC	Text	Capacity expansion switch
RFETSWTC	Text	Ethanol supply curve switch
RFHIST	Text	History switch
RFPCKYR	Integer	Pack file year
RFROSSWTC	Text	ROS switch, on or off
RPT1SWTC	Text	Report 1 switch
RPT7SWTC	Text	Report 7 switch
RPT1YR1	Text	Report 1 switch
RPT1YR2	Text	Report 1 switch
RPT1YR3	Text	Report 1 switch
RPT1YR4	Text	Report 1 switch
RPT1YR5	Text	Report 1 switch
RPT1YR6	Text	Report 1 switch
RPTFY	Integer	Reporting first year
RPTLY	Integer	Reporting last year
STEOBMSW	Integer	STEO benchmarking switch
STMTBSWT(MNUMCR)	integer	Flag for state MTBE ban (0=no ban)
STMTBYR(MNUMCR)	year	1st year of state MTBE ban
WTRGSW	integer	Switch for alternate cal of west coast TRG

Legend for Codes

MNUMYR = NEMS year index, 1 through 31
MNUMCR = census region index, 1 through 11
MNUMPR = PAD District index, 1 through 6
MNUMOR = Oil and Gas Region Index, 1 through 13
MNCROP = Ethanol supply crop index, 1 and 2
MNETOH = Ethanol supply curve point index 1 through 5

A.2 Data Sources

The PMM data have been developed by EIA and others since DOE received the first model database from Turner, Mason Associates during 1975-76. These data were used extensively during 1983-1986 during the development of the EIA Refinery Yield Model (RYM). The RYM database underwent substantial review and update by oil industry experts when the National Petroleum Council (NPC) used the RYM during the development of their 1986 study on U.S. refining flexibility. In 1985, EIA provided the updated RYM/NPC data and OMNI matrix and report generator programs to Oak Ridge National Laboratories (ORNL), and its consultant EnSys, to support a study for the U.S. Navy.[1] The data used for this version of PMM was provided by EnSys to EIA in June 2002 and is based on some EnSys in-house data sources. The data sources include:

- The original Refinery Yield Model (RYM) Data Base provided by EIA in about 1981 to ORNL. This data was then combined with the 1985 RYM/NPC updates and used by their consultant, EnSys.
- *Oil & Gas Journal*, *Hydrocarbon Processing*, NPRA papers, API papers, ASTM specs and correlation methods, *Chemical Engineering*, Gary & Handwerk (mainly correlations), AIChE papers, *Petroleum Review*.
- An extensive review of foreign journals obtained with the aid of ORNL for the high-density jet fuel study.
- Contractor reports and data - M.W. Kellogg, UOP, IFP, Snam Projetti and Foster and Wheeler.
- Consultant reports and data as published - Bonner & Moore, A.D. Little, Chem Systems, Purvin & Gertz, and National Energy Technology Laboratory.

A.2.1 Process Technology and Cost Data

Refining process technology and cost data need periodic review and update. This is because environmental legislation, lighter product slates, and heavier crude slates have spurred new process technology developments affecting existing processes, new processes, and costs. Sources for new developments include research and other papers in industry journals, papers from industry conferences and surveys (such as NPRA), engineering and licensing contractor data, and published consultant studies.

A.2.2 Refinery Capacity Construction and Utilization Data

The base capacity for refinery process units are derived principally from EIA data and annual surveys published in the *Oil & Gas Journal*. The approach used is to review all announced projects, but to only include as active those that have reached the engineering, construction, or start-up stage. (Unit capacity is measured in calendar days.) Historical process unit utilization is derived from the EIA *Petroleum Supply Annual*.

[1]Oak Ridge National Laboratory, EnSys Energy and Systems, *Enhancement of EIA Refinery Evaluation Modeling System Refinery Yield Model Extension and Demonstration on Gasoline and Diesel Quality Issues*, (August 1988).

It is also necessary to track capacity for MTBE and TAME plants, both in-refinery and merchant. Principal sources for these data are EIA surveys, *Fuel Reformulation*, and the *Pace Petrochemical Service* publications.

A.2.3 Crude Supply and Product Demand Data

The crude oil supply is provided by two of the NEMS models: OGSM, which provides the production function to estimate the domestic oil production, including Alaska; and, the International Energy Model which provides volumes and prices of imported crude oils in the form of supply curves. Individual crude oil streams for both domestic and imported crude oils are grouped in five categories differentiated by API gravity, sulfur content, and the yield of material boiling at a temperature higher than 1050 degrees Fahrenheit. The import supply curve values are stored in the NEMS restart file. Each year of a NEMS run contains quantities and import prices for crude oil in three step supply increments for each of the importing PMM regions (E=PADD I, B=PADD's II,III,IV, and W=PADD V).

Both domestic and imported crude oils are grouped in the five categories shown below. While the domestic and foreign categories have the same gravity and sulfur definitions, the composite characteristics of each type may differ because different crude streams make up the composites. The five domestic crude groups are tagged with the codes DLL, DMH, DHL, DHH, and DHV. The imported crude oil codes are FLL, FMH, FHL, FHH, and FHV. In addition, Alaska North Slope and Alaska South are included as individual crude oil streams for a total of 12 crude groups.

Table A2. Aggregate Crude Oil Categories for PMM/NEMS

Description	Code	API Gravity	Sulfur, Wt%	Bottoms Yield, 1050 F+ Vol %
Low Sulfur-Light	LL	> 24	0.5 MAX	< 15%
Medium Sulfur - Heavy	MH	> 24	0.35-1.1	> 15%
High Sulfur - Light	HL	> 32	> 1.1	< 15%
High Sulfur - Heavy	HH	24-33	> 1.1	> 15%
High Sulfur - Very Heavy	HV	< 23	> 0.7	> 15%

Source: Derived from analysis of EIA-810, Monthly Refining Report.

Natural Gas Liquids (NGL's)

The NGL's are produced by the gas plant model matrix that is a part of PMM. See Appendix F (section F.2).

Other Hydrocarbons and Alcohols

Other hydrocarbons such as propane and butanes are supplied by the output of the gas plant model. Ethanol is supplied by the Biofuels Supply Submodule within the PMM (Appendix I). Two sources of ethanol are modeled: ethanol from corn in Census Divisions 3, 4, 6, 8, and 9, and ethanol from cellulose in Census Divisions 2, 3, 4, 7, and 9. The supply of ethanol is represented as a step function with each increment of supply available at a higher price.

Some methanol is imported with the balance required by PMM supplied by the methanol plant in each refining region. Methyl Tertiary Butyl Ether (MTBE) is produced by MTBE plants (both merchant and refinery locations) in each refining region; additional supplies are imported.

Products

Product demands are available from the NEMS restart file for a given scenario by year as produced by the various demand models of NEMS.

A.2.4 Product Specification/Grade Split Data

For the United States, surveys by industry organizations such as NPRA, API, NPC, and NIPER, together with government sources such as 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.

A.2.5 Transportation Data

PMM transportation data for the United States on capacities and rates was originally developed from the OSPR NACOD Model and updated for environmental costs reflecting the Oil Pollution Control Act. The current transportation costs were based on a 1993 study by National Petroleum Council and updated in 1999 based on Federal Energy Regulatory Commission (FERC) data for the oil pipelines.

A.2.6 Product Yield and Quality Blending Data

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

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).

Wt. percent hydrogen - ASTM Method D3343 (replacing D1018)

Smoke point vs. 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 - ibid., p.175.

RVP blending indices have been gathered from several public and in-house sources and have been verified against Gary & Handwerk, p.166.

RON and MON blending deltas are reflective of base gasoline sensitivity have been drawn from many sources and averaged.

A.2.7 Units of Measurement

The general rule adopted in the model is that quantities of oil are in thousands of barrels per calendar day, prices or costs are in 1987 dollars per barrel, and quantities of money are, therefore, in thousands of 1987 dollars per calendar day.

Exceptions to the above rule are:

1. Gases lighter than propane are measured in thousands of barrels fuel oil equivalent (FOE) per day. These are based on the following conversion factors:

Gas stream	Code	bblFOE/lb	cf/bblFOE
Hydrogen	HH2	.008190	23,077
Hydrogen sulfide	H2S	.001040	10,145
Methane/natural gas	NGS	.003414	6,917
Ethane	CC2	.003245	3,861
Process gas	PGS	.003245	3,861
Ethylene	C2E	.003219	4,180

One barrel FOE is 6.3 million Btu.

2. The assumed Btu content for other major refinery streams is shown below:

Stream	Code	MMBtu/bblFOE
Gasoline	TRG	5.253
Jet Fuel	JTA	5.670
No. 2 Heating Oil	N2H	5.825
Residual Oil	N6I,N6B	6.287
LPG	LPG	3.625
Methanol/gasoline	M85	2.820
Ethanol/gasoline	E85	3.500

3. 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.

4. 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.

5. Process unit capacities are generally measured in terms of feedstock volume. Exceptions are units, principally those with gaseous feeds and liquid products, whose capacities are measured in terms of product volume. These include:

   OLE, ETH, C24, ALK, CPL, DIP, DIM, ARP, C4I, SMD, SOD, MOH, H2P, and SUL.

   Note also that unit activity level of H2P, and SUL activities represents the production of 0.1 thousand fuel oil equivalent barrels of hydrogen and 0.1 thousand short tons of sulfur per day, and uses 0.1 units of capacity.

6. Quality and specification units are those specified in each ASTM test method or are dimensionless (as in the case of blending indices). Gasoline sulfur contents and specs, SPM, are in parts per million by weight, while those for distillates, SPC, are in percent weight.

7. Steam consumption is given in pounds per barrel (lb/bbl). Thus an activity in Mbbl/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 .00493 fuel oil equivalent bbl per day to raise 1 lb/hr of steam is equivalent to 1225 Btu per lb steam.

8. Electricity consumption is in kWh/bbl. Generation is in MkWh/day.

A.3 PMM Model Data Tables

This section describes in detail the function and content of the PMM model data tables used to generate the initial PMM matrix for NEMS. The entries in these tables are Mbbl/cd for volume and $/bbl for costs, unless otherwise noted. With the shift of computer processing to the EIA RS6000 in 1995, the OMNI code was replaced with FORTRAN in conjunction with subroutines from the Optimization Modeling Library (OML). The data table formats used by OMNI were no longer valid which required a change in table format, organization and design from the *AEO95* version. These changes are incorporated into the data tables presented in this section. The MRM code (Appendix G) is still used to convert new data tables from OMNI to the current format. The tables have been grouped into nine categories: Matrix Control, Crude Oil Availability, Other Raw Materials Availability, Product Imports, Product Demands, Crude and Product Transportation, Refinery Capacities and Operations, Product Blending and Specifications, and Refining Technology. All data tables are located in a directory on EIA's network NT server (nems-f8) named N:/default/input.

The reference **(filename)** in the following pages refers to the individual file name with a **.dat** extension which contains the tables described. The symbols (R) and (D) used in the table names represent a PMM refining region (R) or Census division (D) where:

(R)*	Refining Region
E	PAD District I
B	PAD District II
B	PAD District III
B	PAD District IV
W	PAD District V

(D)	Census Division
1	New England
2	Mid Atlantic
3	East North Central
4	West North Central
5	South Atlantic
6	East South Central
7	West South Central
8	Mountain
9	Pacific, including California

*Note: Beginning with *AEO98*, the number of PMM refining regions was changed from five to three, where PADDs I and V remained independent regions E and W, respectively, and PADDs II, III, and IV were aggregated into the single region B.

A.3.1 Matrix Control

This section describes the tables used to control the number of constraints (rows) and column variables in the matrix as well as the stipulations for the limits on constraints and variables.

(refmain)

TABLE RFNREG ***LIST OF ACTIVE PMM REFINING REGIONS***

Column names — One column, PAD.

Row names — One character region codes, E, B, W.

Entries — numeric value for PADD, 1, 2, 5. (PADD's II, III, IV represented by 2)

TABLE DEMNDREG LIST OF ACTIVE CENSUS DIVISION DEMAND REGIONS

Column names — One column, REGION.

Row names — Two character codes, first character is demand region, second character is PMM refining region E, B, W.

Entries — numeric value for Census Division, 1-9.

TABLE RFNEXP ***LIST OF PMM REFINING REGIONS LINKED TO EXPORT REGIONS***

Column names — One column, RFID.

Row names — Two character codes, first character is exporting Census Division, second character is PMM refining region E, B, W.

Entries — numeric value for export regions, 1-5.

TABLE EXPROD ***LIST OF EXPORT PRODUCTS***

Column names — One column, DUMMY.

Row names — Three character product codes

Entries — none

TABLE FORCRD	***LIST OF FOREIGN IMPORT CRUDES***
Column names	One column, DUMMY.
Row names	Three character code for foreign crude group
Entries	none
TABLE WOP	***WORLD OIL PRICE BY YEAR***
Column names	One column, WOP.
Row names	Numeric value for year, e.g. 6 for 1995.
Entries	World Oil Price in 1987 $/bbl.
TABLE USERYEAR	***YEAR FOR MODEL RUN***
Column names	One column, YEAR.
Row names	Three character code, e.g. Y95.
Entries	Numeric value for year, e.g. 6 for 1995.
TABLE YRDOLLAR	***CONVERSION FROM 1987 TO 2001 DOLLARS***
Column names	One column, 2001 (year dollars).
Row names	1987
Entries	Numeric value for converting 1987$ to 2001$.
TABLE ZIRACFAC	***FACTOR FOR IRAC SPREAD***
Column names	One column, DELTA.
Row names	ZIRAC
Entries	Range on average price, $/bbl.
TABLE TRSOVC	***FACTOR TO CONVERT OVC TO 2001$***
Column names	One column, OVC.
Row names	One character PMM refining region code (E,B,W).
Entries	Conversion of variable operating costs to 2001$.

TABLE INVFACT ***INVESTMENT LOCATION AND ENVIRONMENTAL FACTORS***

Column names: LOC, ENV

Row names: One character PMM refining region code (E,B,W).

Entries: Column LOC contains the investment location factor multiplier. Column ENV contains the environmental investment cost multiplier, currently set at 1.0 for all regions.

(akaexp)

TABLE EXPAKA ***PRICE/QUANTITY VALUES FOR ALASKA EXPORTS***

Column names: Two columns, P and Q

Row names: Six rows, three negative shifts N1, N2, N3 and three positive shifts, P4, P5, and P6.

Entries: P column is $/bbl shift from reference price, Q column is bound value on volume supplied.

TABLE PRQAKA ***NGL PRICE QUANTITY FROM ALASKA NORTH SLOPE***

Column names: VOL, TRP, and EXPPRC

Row names: OGSM code A for Alaska.

Entries: Volume limit on NGL supply, MBbl/cd, Transportation cost to region W, pseudo supply price, $/bbl.

TABLE NGLAKA ***NGL COMPOSITION FROM ALASKA***

Column names: One column, PER.

Row names: Three character NGL stream codes.

Entries: Volume fraction composition of NGL's.

(avoids) (no longer used)

TABLE SADELQ ***DELTA FRACTION OF QUANTITIES FOR PRODUCT SHIFTS***

Column names: Six columns, three negative shifts N3, N2, N1 and three positive shifts, P1, P2, and P3.

Row names: First three characters finished product codes.

Entries	Percentage (as a fraction) of demand quantity Q0 as an upper bound. The quantities are based on price shifts of 1 percent, 3 percent, and 9 percent using an elasticity of 0.1 for light products gasoline, jet fuel, heating oil and diesel, and an elasticity of 0.3 for all other products.

(These column activities allow the shift of demands within a price range to help speed convergence in NEMS.)

TABLE SADELPX	***FRACTION OF PRICES FOR EACH QUANTITY SHIFT***
Column names	One column, FACTORS
Row names	Six rows, three negative shifts N1, N2, N3 and three positive shifts, P1, P2, and P3.
Entries	Percentage (as a fraction) of price of import step R3 for imported products.

TABLE PRDAVOID	***LIST OF PRODUCTS FOR AVOIDS***
Column names	One column, DUMMY
Row names	Three character product codes.
Entries	None.

(ngprod)

TABLE SPNGF	***SUPPLY STEP PRICES FOR NATURAL GAS TO REFINERY***
Column names	One column, ALLREG
Row names	Two character names, first character is N (negative shift) or P (positive shift), second character is a number from 1 to 8 representing steps on the supply curve.
Entries	Price increments in $/Mcf from reference well head price.

TABLE SQNGF	***SUPPLY STEP QUANTITIES FOR NATURAL GAS TO REFINERY***
Column names	Two columns, MAX and MIN
Row names	Two character names, first character is N (negative shift) or P (positive shift), second character is a number from 1 to 8 representing steps on the supply curve.
Entries	Volume increments in Bcf from reference quantity supplied.

TABLE SCVAL	***SUPPLY OF NATURAL GAS TO REFINERY***
Column names	Three columns, one for each PMM refining region (E,B,W).
Row names	One row, VOL.
Entries	Volume estimate reference quantity supply in Bcf.

(unfinish)

TABLE UNFEQT	***COEFFICIENTS FOR UNFINISHED OIL IMPORTS***
Column names	Two columns, SLOPE, CONST, that describe the regression equation coefficients.
Row names	One row, XYZ
Entries	Slope and intercept for equation that correlates unfinished oil imports to crude input.
TABLE UNFOIL	***UNFINISHED OIL IMPORT SHARES***
Column names	Three columns, E, B, and PD; represent three types of unfinished oil imports into the PMM refining regions.
Row names	Rows NPP, HGM, and ARB are unfinished oil streams imported to the United States.
Entries	Coefficients under refining regions represent volume fractions. Column PD values are imported costs in $/bbl.

(emish)

TABLE EMUNS	***EMISSIONS FROM PROCESS UNITS***
Column names	Five columns, representing type of emission - VOC, CO1, NOX, SOX, and CAR (Carbon).
Row names	Three character process unit codes.
Entries	Emissions in Mlb/Mbbl for VOC, NOX, SOX. Units of MM lbs/Mbbl for CO1, CAR.

TABLE EMFUM	***EMISSIONS FROM FUEL BURNING***
Column names	Six columns, representing type of emission - VOC, CO1, CO2, NOX, SOX, and CAR (Carbon).
Row names	three character stream codes burned in refinery fuel system.
Entries	Emissions in Mlb/Mbbl for VOC, NOX, SOX. Units of MM lbs/Mbbl for CO1, CO2, CAR.

(fixcols)

TABLES (R)RCOL	***LIST OF VARIABLES TO BE EXCLUDED FOR PMM REGION (R)***
Column names	One column, FCC
Row names	Three character FCC operating mode names
Entries	A 1.0 indicates that column will be fixed at level of 0.0

(distress)

TABLE ZPX	***MAPPING OF DISTRESS IMP0RT COSTS***
Column names	One column, VALUE.
Row names	Three character product codes.
Entries	One character value to map costs ($/bbl): 0=$0; 1=0.1 * import price at import curve step 1; 2=$.99; 3=$.201.

A.3.2 Crude Oil Availability

Crude oil supply availability is provided from two sources: (1) domestic production from the Oil and Gas Supply Model (OGSM), and (2) foreign imports to each refining region with three supply step increments.

(domcrude)

TABLE DCRSUP	***DOMESTIC CRUDE OIL IMPORTS BY OGSM REGION***
Column names	One column for each OGSM region (including Alaska)
Row names	Rows for selected years from Y90 to Y10.
Entries	Production volume in each OGSM region (Mbbl/d)

These values are available from the NEMS restart file for a given scenario.

TABLE DCRSHR	***SHARE BY LOWER 48 CRUDE GROUP***
Column names	One column for each OGSM region (including Alaska)
Row names	Five domestic aggregate crude groups plus two Alaskan groups.
Entries	Fractional share of production volume in each OGSM region

TABLE CREXP	***VOLUME OF CRUDE EXPORTS FROM UNITED STATES***
Column names	Two columns, CRDEXP represents crude oil exports, CRDSPR represents the SPR fill rate.
Row names	One row, VOL.
Entries	Export volume in Mbbl/cd

(crdimprt)

TABLES ICR(crt)(R)	***CRUDE OIL IMPORTS BY CRUDE GROUP (crt) IN PMM REFINERY REGION (R)***
Column names	Six columns, C1,Q1,C2,Q2,C3,Q3
Row names	NEMS year code (1,2,3,etc)
Entries	Columns Q(n) represent the availability in Mbbl/cd of each crude. Columns C(n) show the landed price in 1987 dollars per barrel at each refining region.

(These values are available from the NEMS restart file for a given scenario.)

TABLE CRUDETYP	***TYPES OF FOREIGN CRUDE OIL***
Column names	One column, DUMMY
Row names	Three character codes for foreign crude type
Entries	None.

(ermcrude)

TABLE CRUDEG	***CRUDE OIL QUALITIES AND COSTS FOR REGION G***
Column names	Three columns, CST, MIN, MAX.
Row names	Three character crude codes.
Entries	Objective function cost information; and minimum and maximum crude quantities available.

A.3.3 Other Raw Materials Availability

(ethanol)

TABLE SUPETH(D) ***ETHANOL SUPPLY BY CENSUS DIVISION (D)***

Column names: Eight columns, C1,R1,C2,R2,C3,R3,C4,R4

Row names: NEMS Year code (1,2,3,etc)

Entries: Columns R(n) represent the availability in Mbbl/cd of Ethanol. Columns C(n) show the supply price in dollars per barrel in each Census Division.

(These values are available from the NEMS restart file for a given scenario.)

(Note: T:ETHTAX presented in section A.3.5)

TABLE MINRENEW ***MINIMUM TOTAL STILL GAS CONSUMED AT REFINERY***

Column names: USMIN

Row names: NEMS Year code (1,2,3,etc)

Entries: Minimum total still gas (all regions) consumed at the refinery (M bbl/cd)

TABLE SUPBIM ***PRICE/QTY SUPPLY CURVE FOR BIOFUEL***

Column names: Eight columns, C1,R1,C2,R2,C3,R3,C4,R4

Row names: Census Division demand region ID's (1-9)

Entries: Columns R(n) represent the availability in Mbbl/cd of Ethanol. Columns C(n) show the supply price in dollars per barrel in each Census Division.

(utility)

TABLES (R)UAP ***UTILITY PURCHASES - PMM REFINERY REGION (R)***

Column names: One column, CST.

Row names: Three character codes for purchased utilities: KWH, STM, NGF. (Only STM used. KWH defined using T:VPELIN. NGF defined using T:VALPNG)

Entries: Column CST contains the purchase price of the utility (KWH=1987 dollars/KWh, STM=1987 dollars/lb, NGF=1987 dollars/mcf).

(Note: same table also appears in mchproc.dat)

TABLE UTITRS	***NATURAL GAS PURCHASES***
Column names	One column, COEF.
Row names	One row, NGFNGS.
Entries	Barrels of fuel oil equivalent (BFOE/mcf--conversion factor) of Natural Gas.

TABLE VALPNG	***INDUSTRUAL PRICE OF NATURAL GAS***
Column names	Single character ID for PMM refinery regions (E,B,W).
Row names	NEMS year code (1,2,3, etc.).
Entries	Price of Natural Gas by PMM refinery region (1987 dollars/mcf).

TABLE VPELIN	***INDUSTRIAL ELECTRIC GENERATION PRICES***
Column names	Single character ID for PMM refinery regions (E,B,W).
Row names	NEMS year code (1,2,3, etc.).
Entries	Industrial electric utility prices (converted to 1987 dollars/KWh using 3412 MMBtu/GWh).

(ermother)

TABLE OTHERG	***OTHER RAW MATERIAL QUANTITIES AND COSTS FOR REGION G***
Column names	Three columns, CST, MIN, MAX.
Row names	Three character codes for intermediate streams (raw materials purchased).
Entries	Column CST contains the purchase price of the raw material; columns MIN and MAX contain minimum and maximum quantities of each material allowed to be purchased.

A.3.4 Product Imports

(prdimprt)

TABLES IPR(prd)(R) PRODUCT IMPORTS TO PMM REFINERY REGION (R)

Column names: Six columns, C1,R1,C2,R2,C3,R3

Row names: NEMS Year code

Entries: Column R(n) represent the availability in Mbbl/cd of each product (PRD) imported. Columns C(n) show the landed price in dollars per barrel at each refining region.

(These values are available from the NEMS restart file for a given scenario.)

TABLE NEMSRSD IMPORTED RESIDUAL OIL SUPPLY QUANTITY AND PRICE

Column names: Two columns, R1B is fraction of step 1 import quantity, R1PR is multiplier of step 1 price in increments of 2 percent.

Row names: R1 through R9. Step name increments.

Entries: R1B is fraction of step 1 import level. R1PR is price level over step 1 price.

TABLE IMPLIM LIMIT ON U.S. PRODUCT IMPORTS

Column names: One column MAX

Row names: One row, @ implies all regions.

Entries: Limit on product imports in Mbbl/cd

TABLE PRODTYP LIST OF PETROLEUM PRODUCT IMPORTS

Column names: One column, DUMMY

Row names: Three character product name

Entries: None.

A.3.5 Product Demands

(demand)

TABLES (prd) PRODUCT DEMAND

Column names One column for each Census Division.

Row names NEMS Year code.

Entries Demand in Mbbl/cd

(These demands are available from the NEMS restart file for a given scenario.)

(Note: RFHA represents product RFH in T:RFHA)

TABLE PRODLIST LIST OF PRODUCT FOR DEMANDS

Column names One column DUMMY

Row names Three characters for finished product codes.

Entries None.

(Note: RFHA represents product RFH due to a table name conflict in data file **refproc**)

TABLE DEMMET CHEMICAL METHANOL DEMAND

Column names One column CHEM for volume demand by chemical industry.

Row names NEMS Year code.

Entries Demand volume in Mbbl/cd

(Note: T:CKSMIX is presented in section A.3.8)

(prdexp)

TABLE (D)PRDEXP PRODUCT EXPORTS FROM CENSUS DIVISION (D)

Column names Ten columns, a MIN and MAX for 5 years: MINY1, MAXY1, MINY2, MAXY2, MINY3, MAXY3, MINY4, MAXY4, MINY5, MAXY5

Row names YEAR, and three character export finished product codes.

Entries Export volume in Mbbl/cd

(Note: (D) represents CDs 2,3,7,8,9 only--product export regions)

TABLE EXPLIM	***LIMIT ON PRODUCT EXPORTS***
Column names	Two columns, YRPC and FIX for percent per year growth and fixed volume for the start year.
Row names	The start year, i.e. 1995
Entries	YRPC value is multiplier for growth. FIX column is in Mbbl/cd.

TABLE MULTEXPR	***PRICE MULTIPLIER FOR PRODUCT EXPORTS***
Column names	One column MULT.
Row names	Price
Entries	Multiplier for export price as function of step 1 import price.

(ethanol)

TABLE ETHTAX	***ETHANOL TAX SUBSIDY***
Column names	Two columns, TAXETH, TAXE85.
Row names	NEMS year code (1,2,3,etc)
Entries	Tax subsidy (1987 dollars/bbl).

(ermprod)

TABLE PRODUCTG	***PRODUCT DEMANDS AND REVENUES FOR REGION G***
Column names	Three columns, REV, MIN, MAX.
Row names	Three character product codes.
Entries	Objective function revenue information; and minimum and maximum product demands.

A.3.6 Crude and Product Transportation

Transportation links are specified for movements between all regions in the model; from domestic crude oil supply regions (Oil and Gas Supply Model - OGSM), crude oil import regions, refining regions, and demand regions. Modes of transportation are provided for marine vessel, pipeline, and barge/truck. Explicit pipelines were identified and aggregated where necessary to represent links from refining regions to Census divisions. The table name structure uses the following first two characters to represent the corresponding modes of transportation - TP for tanker movements, PL for pipeline and BV for Barge/Truck. Characters 3 and 4 are CR for crude oil, PR for products, and LG for LPG. Shipping costs are in dollars per barrel from a source to a destination region. The value must be negative to allow movement. A positive value indicates a disallowed movement. An explicit zero indicates a no cost movement.

(transit)

TABLES TPCR(S)	***DOMESTIC CRUDE MOVEMENTS (TANKER) EXITING OGSM REGION (S)***
Column names	Crude group domestic, three characters; and GTL (gas to liquids stream).
Row names	First character is mode code; second character, code for destination refining region; and TAPS (Trans Alaska Pipeline System).
Entries	Shipping cost in dollars per barrel to destination region.
TABLES PLCR(S)	***DOMESTIC CRUDE MOVEMENTS (PIPELINE) EXITING OGSM REGION (S)***
Column names	Crude group domestic, three characters.
Row names	First character is mode code; second character, code for destination refining region.
Entries	Shipping cost in dollars per barrel to destination region.
TABLES TPPR(R)	***PRODUCT SHIPPING COSTS (TANKER) EXITING REGION (R)***
Column names	Codes for finished products that are shipped by tanker.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in dollars per barrel.
TABLES PLPR(R)	***PRODUCT SHIPPING COSTS (PIPELINE) EXITING REGION (R) OR CENSUS DIVISION (D)***
Column names	Codes for finished products that are shipped by pipeline.

Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl.

TABLES BVPR(R) ***PRODUCT SHIPPING COSTS (BARGE/TRUCK) EXITING REGION (R)***

Column names	Finished product codes for shipments by barge and/or truck.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl.

TABLES TPME(R) ***METHANOL SHIPPING COSTS EXITING REGION (R)***

Column names	MET for methanol.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl.

TABLES TPET(D) ***ETHANOL SHIPPING COSTS EXITING CENSUS DIVISION (D)***

Column names	ETH for ethanol.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl. (Note: mode M represents qty-wt average for modes rail, truck, vessel, barge transport costs.)

TABLES TPBD(D) ***BIOMASS DIESEL SHIPPING COSTS EXITING CENSUS DIVISION (D)***

Column names	BIM for biomass diesel.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl.

TABLES PLLG(R)	***LPG & PCF SHIPPING COSTS (PIPELINE) EXITING REGION (R)***
Column names	LPG and Petrochemical Feed (PCF) products that are shipped by pipeline.
Row names	Transportation mode (one character) and destination region codes (one character) for a total of two characters.
Entries	Shipping cost in $/bbl.

TABLE MVCCAP	***MARINE VESSEL (CRUDE AND PRODUCTS) CAPACITY***
Column names	MAX for maximum capacity
Row names	TVC (crude) or TVP (product), each followed by transportation mode (one character) and CP
Entries	Capacity in thousands of dead weight tons (DWT)

TABLE PLCCAP	***PIPELINE (CRUDE, PRODUCTS, AND LPG) CAPACITY***
Column names	MAX for maximum capacity
Row names	TPC (crude), TPP (products), or TPL (LPG), each followed by source region code (one character), transportation mode (one character) and destination region code (one character)
Entries	Capacity in Mbbl/cd

TABLE BVPCAP	***MARINE BARGE (PRODUCTS) CAPACITY***
Column names	MAX for maximum capacity
Row names	TVP followed by transportation mode (one character) and CP
Entries	Capacity in thousands of dead weight tons (DWT)

TABLE PLNK(R)	***PRODUCT PIPELINE TRANSPORT EXITING REGION (R) OR CENSUS DIVISION (D)***
Column names	Three character codes for finished products.
Row names	Transportation mode (one character) and destination region code (one character) for a total of two characters. Currently shipped from PADD 3 (G) and CD 6 to CD 5 and CD 6.
Entries	Cost of product pipeline transport

A.3.7 Refinery Capacities and Operations

(refproc)

TABLES (R)CAP	***REFINING CAPACITIES - PMM REFINERY REGION (R)***
Column names	CAP, PUL, and BLD.
Row names	Process unit codes.
Entries	Column CAP contains existing unit capacities in thousands of barrels per calendar day capacity (MBbl/cd). Column PUL contains fractional utilizations, which convert nameplate calendar day capacity to capacity available to the PMM model. The PUL factors represent actual utilizations and will vary from unit to unit, from region to region, and from case to case. These factors are used to control over optimization. Column BLD contains a 1.0 if a unit can be expanded, otherwise a 0.0 means no capacity expansion for that unit.
TABLE MATBAL	***STREAMS REQUIRING MATERIAL BALANCE CONSTRAINTS***
Column names	One column, A (B not used).
Row names	Three character intermediate stream codes.
Entries	A flag (1=yes) indicating a need for material balance constraint on intermediate stream.
TABLES (uns)	***REFINERY PROCESS UNIT YIELDS AND OTHER OPERATIONS*** (See Section A.3.9 for detailed information on specific processing units.)
Column names	Three character process operating mode.
Row names	Three character input/output stream codes; three character utility codes; three character policy codes; and CAP.
Entries	Consumption and yield fractions for streams, utilities (bbl output/bbl input); costs for OVC (2001 dollars/bbl—converted in matrix to 1987 dollars using T(r)OVCOBJ variable and T:TRSOVC data for year 2001).

TABLE INV ***INVESTMENT PARAMETERS REFINERY UNITS***

Column names INV, FXOC, CAPREC.

Row names Process unit codes.

Entries Column INV contains investment in 2001 dollars/bbl, FXOC has the fixed operating cost in 2001$/bbl, and CAPREC has the daily annualized investment cost 2001 dollars/bbl. (All dollars converted to 1987 dollars in MRM code using YRDOLLAR data.)

This table provides the investment parameters required for the total annualized cost of investment and fixed cost coefficients which are placed on the process unit expansion activities. These values are generated offline and used as initial investment parameters in the LP matrix. These values are updated in the refine.f code each year to reflect changes in investment costs (see Appendix F.1).

The capital recovery factor is built up from cost of capital, economic life, depreciation life and tax rate. Straight-line depreciation is assumed and depreciation is considered as an expense to be offset as a tax credit against the tax burden. The calculated capital recovery factor is on an after-tax basis and the resultant investment purchase vector costs are on the same basis.

TABLE SCL ***SCALE FACTORS FOR TABLE COEFFICIENTS***

Column name Processing unit name (Three-Character code)

Row names Intermediate stream or utility name (Three-Character code, e.g., FUL, OVC, LOS, HH2, etc).

Entries Constants, multiples of 10 (e.g., 1000, 0.001, etc) to help control the size of the coefficient.

(limpol)

TABLE UNITPOL ***PROCESS UNITS WITH POLICY ROW CONSTRAINTS***

Column name DUMMY

Row names The three-character row names correspond to processing units that have policy limits. These units are described below as tables LIM(uns)(r).

Entries None.

(Note: the entries in tables LIM(uns)(r), which represent fraction of throughput, will appear as entries in the column Z(r)FLO(uns). The current set of (uns) are: FCC, RFL, RFH, DDS, FUM, KRF, ETH, and ETM.)

TABLE LIM(uns)(R) POLICY LIMITS FOR EACH PMM REFINERY REGION (R)

Column name — Three-character policy limit code.

Row names — One row, DUM.

Entries — A value representing a volume fraction of the process unit capacity for the restriction, i.e. 0.99 stipulates that this mode will be limited to 99 percent of the units total capacity. The total capacity is the sum of the existing capacity, builds, and new capacity expansion.

(accunit)

Atmospheric distillation refinery process unit. This unit characterizes the crude oils by differentiating the yields of the following fractions:

Name	Quality	Description	Stream Mnemonic code
GAS (C2 & lighter)			PGS
C3			CC3
IC4			IC4
NC4			NC4
LSR (C5-175)	LON	low octane	SRL
LSR (C5-175)	ION	intermediate octane	SRI
LSR (C5-175)	HON	high octane	SRH
LT NAPH (175-250)	P	paraffinic	LNP
LT NAPH (175-250)	I	intermediate	LNI
LT NAPH (175-250)	N	naphthenic	LNN
NAPH (250-325)	P	paraffinic	NPP
NAPH (250-325)	I	intermediate	NPI
NAPH (250-325)	N	naphthenic	NPN
H N/L J(325-375)	P/LF	paraffinic low freeze pt. index	JPL
H N/L J(325-375)	I/LF	intermediate low freeze pt. index	JIL
H N/L J(325-375)	N/LF	naphthenic low freeze pt. index	JNL
H N/L J(325-375)	P/HF	paraffinic high freeze pt. index	JPH
H N/L J(325-375)	I/HF	intermediate high freeze pt. index	JIH
H N/L J(325-375)	N/HF	naphthenic high freeze pt. index	JNH
KERO(375-500)	LF/LL/LS	low fz pt., low smoke pt., low sulfur	KLL
KERO(375-500)	LF/LL/HS	low fz pt., low smoke pt., high sulfur	KLH
KERO(375-500)	LF/HL/LS	low fz pt., high smoke pt., low sulfur	KHL
KERO(375-500)	LF/HL/HS	low fz pt., high smoke pt., high sulfur	KHH
KERO(375-500)	HF/LL/LS	high fz pt., low smoke pt., low sulfur	1LL
KERO(375-500)	HF/LL/HS	high fz pt., low smoke pt., high sulfur	1LH
KERO(375-500)	HF/HL/LS	high fz pt., high smoke pt., low sulfur	1HL
KERO(375-500)	HF/HL/HS	high fz pt., high smoke pt., high sulfur	1HH
HKERO(500-550)	LF/LL/LS	low fz pt., low smoke pt., low sulfur	3LL
HKERO(500-550)	LF/LL/HS	low fz pt., low smoke pt., high sulfur	3LH
HKERO(500-550)	LF/HL/LS	low fz pt., high smoke pt., low sulfur	3HL
HKERO(500-550)	LF/HL/HS	high fz pt., low smoke pt., low sulfur	3HH
HKERO(500-550)	HF/LL/LS	high fz pt., low smoke pt., low sulfur	4LL
HKERO(500-550)	HF/LL/HS	high fz pt., low smoke pt., high sulfur	4LH
HKERO(500-550)	HF/HL/LS	high fz pt., high smoke pt., low sulfur	4HL
HKERO(500-550)	HF/HL/HS	high fz pt., high smoke pt., high sulfur	4HH
DSL B(550-650)	LP/LC/LS	low pour pt., low cetane index, low sulfur	DLL
DSL B(550-650)	LP/LC/HS	low pour pt., low cetane index, high sulfur	DLH
DSL B(550-650)	LP/LC/MS	low pour pt., low cetane index, medium sulfur	DLM
DSL B(550-650)	LP/HC/MS	low pour pt., high cetane index, medium sulfur	DHM
DSL B(550-650)	LP/HC/LS	low pour pt., high cetane index, low sulfur	DHL
DSL B(550-650)	LP/HC/HS	low pour pt., high cetane index, high sulfur	DHH
DSL B(550-650)	HP/LC/LS	high pour pt., low cetane index, low sulfur	2LL
DSL B(550-650)	HP/LC/MS	high pour pt., low cetane index, medium sulfur	2LM
DSL B(550-650)	HP/LC/HS	high pour pt., low cetane index, high sulfur	2LH
DSL B(550-650)	HP/HC/LS	high pour pt., high cetane index, low sulfur	2HL
DSL B(550-650)	HP/HC/MS	high pour pt., high cetane index, medium sulfur	2HM

Name	Quality	Description	Stream Mnemonic code
DSL B(550-650)	HP/HC/HS	high pour pt., high cetane index, high sulfur	2HH
DSL C(650-690)	LP/HC/LS	low pour pt, high centane index, low sulfur	6HL
DSL C(650-690)	LP/HC/HS	low pour pt, high centane index, high sulfur	6HH
DSL C(650-690)	LP/LC/LS	low pour pt, low centane index, low sulfur	6LL
DSL C(650-690)	LP/LC/HS	low pour pt, low centane index, high sulfur	6LH
DSL C(650-690)	HP/LC/HS	high pour pt, low centane index, high sulfur	7LH
DSL C(650-690)	HP/HC/LS	high pour pt, high centane index, low sulfur	7HL
DSL C(650-690)	HP/HC/HS	high pour pt, high centane index, high sulfur	7HH
LGO (690-800)	N,LS	naphthenic, low sulfur	LGL
LGO (690-800)	N,MS	naphthenic, medium sulfur	LGM
LGO (690-800)	N,HS	naphthenic, high sulfur	LGH
LGO (690-800)	P,LS	paraffinic low sulfur	LGP
HGO FD(800-1050)	NAP,LS	naphthenic, low sulfur	HGL
HGO FD(800-1050)	NAP,MS	naphthenic, medium sulfur	HGM
HGO FD(800-1050)	PFN,LS	paraffinic low sulfur	HGP
VAC RES	V LO SUL (0.5)	very low sulfur	RSL
VAC RES	HI SUL (2.3)	high sulfur	RSH
ATMOS RED CRUDE	(A-M)	Type A through M	ARA-M

Data sources are the parent Turner Mason model data (vintage 1978) provided to ORNL by EIA (vintage 1985) and thereafter to EnSys and in-house EnSys assay data. These have been collected and compared from many sources and progressively built into the model. Assay data for stored SPR crude oils were obtained from U. S. Department of Energy, *"Strategic Petroleum Reserve Crude Oil Stream Quality Characteristics"*, August 1, 1990.

In the past, crude oil quality information resided in the **crdval.dat** data file used for PMM matrix generation. It has been transferred into two MSAccess database files residing on the EIA LAN at the following location:

\\FS-F1\L6007\PRJ\MSACCESS\CRD95GRP (MRM processing)
\\FS-F1\L6007\PRJ\MSACCESS\CRD95IND (ERM processing)

The database file contains quantity, API gravity, sulfur, grade, and source information on individual crude oil streams. Macro programs have been developed to process this data to generate the following set of tables now residing in the **accunit.dat** data file: ***Table ACUCUTS***, ***Table ACUPOL***, and ***Table ACUUTI***. Note that the ***Table ACUCUTS*** yields have been volume balanced to 0; i.e., total yields equal 1.0 exactly. Process losses are accounted for using ***Tables PFA*** and ***REL***.

TABLE ACUCUTS ***ATMOSPHERIC DISTILLATION YIELD FOR CRUDE OILS***

Column names — Three character crude stream group code AMH for Alaska North Slope, ALL for Alaska Light, D(ll) for domestic crude oils and F(ll) for imported crude oils.

Row names — Three character intermediate stream codes.

Entries — Volume fractions (bbl Output/bbl Input).

TABLE ACUPOL ***ATMOSPHERIC DISTILLATION NON-YIELD VALUES FOR CRUDE OILS***

Column names — OVC for variable operating cost and LOS for losses

Row names	Three character crude stream group codes
Entries	OVC: 2001 dollars/bbl (converted in matrix to 1987 dollars using T(r)OVCOBJ variable and T:TRSOVC data for year 2001). Volume fractions (bbl Output/bbl Input) for LOS.

TABLE ACUUTI ***ATMOS. DISTILLATION UTILITY CONSUMPTION FOR CRUDE OILS***

Column names	KWH and STM
Row names	Three character crude stream group codes
Entries	Electricity (kWh/bbl) and steam (lb/bbl).

TABLE INVLIM ***INVESTMENT LIMIT BY REGION***

Column names	MAX
Row names	One character PMM refinery region code and @ for total United States.
Entries	Million dollars of total capacity expansion investment.

(setrows)

TABLES (R)POL ***REFINERY POLICY CONSTRAINTS - PMM REFINERY REGION (R)***

Column name	TYPE.
Row names	The three-character row names correspond to processing constraints (as discussed below).
Entries	A non-blank entry in the TYPE column causes generation of a row of corresponding type, either a max (1.0), min (-1.0), fixed (0.0), or free (99.0).

The process constraint rows in the current formulation are as follows:

SVR, SVH, SVL, SVC limit severity on FCC, RFH, RFL and RFC respectively.

PFH, PFU, PFB limit H_2S, very low (0.3 percent), low (1 percent), and high (3 percent) sulfur fuel oil[2] to refinery fuel respectively.

FLX limits the use of flexicoking activities (which are actually depicted as modes of operation of the fluid coker) to the level of known flexicoker (KRF) capacities.

[2]PFH, PFU and PFB are used to set the amount of residual fuel input to refinery fuel, generally based on historical data. If left uncontrolled, resid input to refinery fuel can swing wildly and unrealistically.

MSL, MSR, FCR, MSD, MSZ, are used to control FCC activities:

- MSL: maximum use of light olefin modes
- MSR: maximum low sulfur residue feed
- FCR: maximum high sulfur residue feed
- MSD: maximum distillate feed
- MSZ: maximum use of ZSM high octane catalyst

MXU, L00, L05, H00, H05, C05, control reformer operations (RFL, RFH):

- MXU: maximum use of R62 high octane catalyst on the RFL unit
- L00, L05: maximum use of 100 and 105 severity on the RFL unit
- H00, H05: maximum 100 and 105 severity on the RFH unit
- C05: maximum 105 severity operation of the RFC unit

DKU and DDU limit deep desulfurization of kerosene/heavy kerosene and of diesel/light cycle oil in the distillate desulfurizer (DDS).

(nrfplant)

TABLE INVMOH	***INVESTMENT PARAMETERS METHANOL PLANT***
Column names	INV, CAPREC, FXOC
Row names	Process unit MOH.
Entries	Column INV contains investment in 2001 dollars/bbl, CAPREC has the daily annualized investment cost (2001 dollars), and FXOC has the fixed operating cost in 2001 dollars/bbl. (All dollars converted to 1987 dollars in MRM code using YRDOLLAR data.)

This table provides the methanol plant investment parameters required for the total annualized cost of investment and fixed cost coefficients which are placed on the process unit expansion activities. These values are generated offline.

TABLE GASPLT	***GAS LIQUIDS PROCESSING PLANT***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	DGP, (gas plant feed), PGS, CC3, IC4, NC4, NAT, (Natural Gas Liquids NGL's), OVC operating cost, LOS processing loss.
Entries	Gas plant feed coeff is ratio of wet gas (Bcf/day) to dry gas (Bcf/day); yields coeff is Mbbl/Bcf of dry gas.

TABLE GASSHFT	***ALLOW SHIFT OF ETHANE AND PROPANE TO NATURAL GAS***
Column names	Two columns, SC2 for shift of ethane to natural gas, SC3 for shift of propane to natural gas.
Row names	CC1, (natural gas), LOS processing loss, and OBJ.
Entries	Amount shifted from gas plant yield to natural gas in Mbbl/Bcf. OBJ represents credit for gas plant operating costs.
TABLE GASCAP	***CAPACITY OF GAS PLANT***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	FAC, gas residue factor, CAP, gas plant capacity, LIM, limit on propane shift, PCU, percent utilization.
Entries	Gas plant feed and CAP in Bcf/day, FAC is volume fraction, LIM in Mbbl/cd, PCU is percent utilization.
TABLE MOHPLT	***METHANOL PLANT***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	CC1, (natural gas feed), MET methanol output, OVC operating cost, KWH electricity consumption.
Entries	Natural gas feed coeff is in mcf/bbl (used to define feed qty in MMcf/day), yields in Mbbl/cd of methanol.
TABLE MOHCAP	***CAPACITY OF METHANOL PLANT***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	One row, CAP.
Entries	Plant capacity in Mbbl/cd.
TABLE CC1CAP	***DRY GAS PRODUCTION (DGP) CAPACITY***
Column names	Three columns, (R)01 for each PMM refining region (R)=E,B,W.
Row names	NEMS year code (1,2,3,etc)
Entries	Dry gas production capacity in BCF/day.

TABLE (R)CAPMCH MERCHANT PLANT CAPACITIES - PMM REFINING REGION (R)

Column names	CAP, PUL, and BLD
Row names	Process unit codes - C4X, OLX, ETX, FUX, STX, SMD, SOD.
Entries	Column CAP contains existing unit capacities in thousands of barrels per calendar day capacity (MBbl/cd). Column PUL contains fractional utilizations, which convert nameplate calendar day capacity to capacity available to the PMM model. The PUL factors represent actual utilizations and will vary from unit to unit, from region to region, and from case to case. These factors are used to control over optimization. Column BLD contains a 1.0 if a unit can be expanded, otherwise no capacity expansion allowed for that unit.

TABLES (uns)POL MERCHANT PLANT (uns) POLICY ROW CONSTRAINTS

Column names	OVC for variable operating cost and LOS for losses
Row names	Three character mode.
Entries	OVC: 2001 dollars/bbl (converted in matrix to 1987 dollars using T(r)OVCOBJ variable and T:TRSOVC data for year 2001). LOSS: Volume fractions (bbl Output/bbl Input).

TABLES (uns)UTI MERCHANT PLANT (uns) UTILITY CONSUMPTION FOR PROCESSING

Column names	KWH and STM
Row names	Three-character mode.
Entries	Electricity (kWh/bbl) and steam (lb/bbl).

TABLES (uns)CAP MERCHANT PLANT (uns) CAPACITY FACTOR

Column names	One column, CAP
Row names	Three-character mode.
Entries	Capacity factor.

TABLES (uns)REP MERCHANT PLANT (uns) PROCESS YIELDS

Column names	Three-character process mode codes.
Row names	Three-character intermediate stream codes.
Entries	Volume fractions (bbl output/bbl input).

TABLE TRANSFER MAPPING OF STREAM TRANSFERS BETWEEN PLANTS

Column names	One column, DUMMY.

Row names Two-character plant code - GP, MP, or RF.

Entries No entry.

TABLES MPTRANS1 STREAM TRANSFER COSTS FOR GTL AND CTL OUTPUT STREAMS

Column names Three-character processing unit code - GTLRF and CTLRF (transfer to refinery).

Row names Three-character intermediate stream codes.

Entries Cost of transferring stream from offsite facility to refinery (dollars/bbl).

TABLES (xx)TRANS STREAM TRANSFER COSTS ACROSS PLANTS

Column names Two-character plant code - GP, MP, or RF.

Row names Three-character intermediate stream codes.

Entries Cost of transfering stream across plants (dollars/bbl).
(xx = GP (gas plant), MP (merchant plant), RF (refinery).)

TABLE MCHINV INVESTMENT PARAMETERS FOR MERCHANT PLANT UNITS

Column names INV, FXOC, CAPREC.

Row names Three-character process unit codes.

Entries Column INV contains investment in 2001 dollars/bbl, FXOC has the fixed operating cost in 2001 dollars/bbl, and CAPREC has the daily annualized investment cost 2001 dollars/bbl. (All dollars converted to 1987 dollars in MRM code using YRDOLLAR data.)

(cogener)

TABLE CGNCAP REFINERY COGENERATION PLANT CAPACITIES

Column names CAP, PUL, and BLD

Row names One-character PMM refinery region ID (E,B,W).

Entries Column CAP contains existing cogeneration capacities in kWh/day units.

Column PUL contains fractional utilizations, which convert nameplate calendar day capacity to capacity available to the PMM model. The PUL factors represent actual utilizations and will vary from unit to unit, from region to region, and from case to case. These factors are used to control over optimization.

Column BLD contains a 1.0 if a unit can be expanded, otherwise no capacity expansion allowed.

TABLE CGNINV	***INVESTMENT PARAMETERS FOR REFINERY COGENERATION UNITS***
Column names	Three columns: INV, FXOC, CAPREC
Row names	One-character PMM refinery region ID (E,B,W).
Entries	Column INV contains investment in 2001 dollars/bbl, FXOC has the fixed operating cost in 2001 dollars/bbl, and CAPREC has the daily annualized investment cost 2001 dollars/bbl. (All dollars converted to 1987 dollars in MRM code using YRDOLLAR data.)
TABLE CGNPOL	***REFINERY COGENERATION POLICY ROW CONSTRAINTS***
Column names	OVC for variable operating cost.
Row names	One row, three-character mode - CGN.
Entries	OVC: 2001 dollars/bbl (converted in matrix to 1987 dollars using T(r)OVCOBJ variable and T:TRSOVC data for year 2001).
TABLE CGNUTI	***UTILITY CONSUMPTION FOR REFINERY COGENERATION***
Column names	KWH and STM
Row names	One-character PMM refinery region ID (E,B,W).
Entries	Electricity (kWh/bbl) and steam (lb/bbl).
TABLE CGNREP	***REFINERY COGENERATION FUEL CONSUMPTION***
Column names	One column, CGN
Row names	One row, FUL
Entries	Fuel consumption
TABLE SELCGN	***REFINERY COGENERATION SALES BY PADD***
Column names	One column, SOLD
Row names	One character PMM refinery region ID (E,B,W).
Entries	Fraction sold in each PADD.
TABLE VPELAS	***ELECTRIC UTILITY PRICES FOR REFINERY COGENERATION***
Column names	One-character PMM refinery region ID (E,B,W).
Row names	NEMS year code (1,2,3,etc).
Entries	Electric utility prices converted to 1987 dollars/Kwh using 3412 MMBtu/Gwh.

TABLE CGXCAP ***MERCHANT COGENERATION PLANT CAPACITIES***

Column names: CAP, PUL, and BLD

Row names: One-character PMM refinery region ID (E,B,W).

Entries: Column CAP contains existing cogeneration capacities in KWh/day units.

Column PUL contains fractional utilizations, which convert nameplate calendar day capacity to capacity available to the PMM model. The PUL factors represent actual utilizations and will vary from unit to unit, from region to region, and from case to case. These factors are used to control over optimization.

Column BLD contains a 1.0 if a unit can be expanded, otherwise no capacity expansion allowed.

TABLE CGXINV ***INVESTMENT PARAMETERS FOR MERCHANT COGENERATION UNITS***

Column names: Three columns: INV, FXOC, CAPREC

Row names: One-character PMM refinery region ID (E,B,W).

Entries: Column INV contains investment in dollars/bbl, FXOC has the fixed operating cost in dollars/bbl, and CAPREC has the daily annualized investment cost.

TABLE CGXPOL ***MERCHANT COGENERATION POLICY ROW CONSTRAINTS***

Column names: OVC for variable operating cost.

Row names: One row, three-character mode - CGN.

Entries: OVC: 2001 dollars/bbl (converted in matrix to 1987 dollars using T(r)OVCOBJ variable and T:TRSOVC data for year 2001).

TABLE CGXUTI ***UTILITY CONSUMPTION FOR MERCHANT COGENERATION***

Column names: KWH and STM

Row names: One-character PMM refinery region ID (E,B,W).

Entries: Electricity (kWh/bbl) and steam (lb/bbl).

TABLE CGXREP ***MERCHANT COGENERATION FUEL CONSUMPTION***

Column names: One column, CGX

Row names: One row, FUL

Entries: Fuel consumption

TABLE SELCGX ***MERCHANT COGENERATION SALES BY PADD***

Column names: One column, SOLD

Row names	One-character PMM refinery region ID (E,B,W).
Entries	Fraction sold in each PADD.

TABLE VPELWS ***ELECTRIC UTILITY PRICES FOR MERCHANT COGENERATION***

Column names	One-character PMM refinery region ID (E,B,W).
Row names	NEMS year code (1,2,3,etc).
Entries	Electric utility prices converted to 1987 dollars/KWh using 3412 MMBtu/GWh.

(stream)

TABLE TRS ***STREAM TO STREAM TRANSFERS***

Column names	Three columns, MIN, MAX, and CST
Row names	Six-character code, consisting of a three character intermediate stream code and another three-character intermediate stream code; and OVCOBJ.
Entries	No entry; except CST column: -1 for OVCOBJ.

Table TRS allows the transfer of one refinery stream to another - the transfer vector names are in the form *xxxyyy* where *xxx* is the source stream code and *yyy* is the destination stream code.

Selected refinery minor finished product sales transfers are included in ***Table TRS***, namely:

- optional condensation of C_3 and C_4 streams into sales LPG. This is useful where data are not separately available for propane and butane sales (Would normally be de-activated through asterisks in *Column 1*.)
- condensation of benzene, toluene, and xylene into AROmatics and BTX sales.

Table TRS is also used for condensation of feed streams for several of the key refinery process units. This economizes on detail in refinery process unit representations at the expense of adding a relatively small number of LP transfer vectors.

The original transfers were derived from the parent Turner Mason model provided to EIA and has been amended and extended by EnSys and EIA.

TABLE XSALE ***STREAM TO PRODUCT TRANSFERS***

Column names	One column, DUMMY.
Row names	Six-character code, consisting of a three character intermediate stream code and a three-character product stream code.
Entries	-- blank --

A.3.8 Product Blending and Specifications

(gasoblnd)

TABLES Q(R)GSL	***REGIONAL GASOLINE SPECIFICATIONS--PMM REGION (R)***
Column names	Finished gasoline codes (RFG and TRG)
Row names	Two character quality codes, followed by X (maximum) or N (minimum).
Entries	Columns contain specification levels for the corresponding qualities.

TABLES (R)SSR	***SUBSPEC RFG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing 5 transition years for changes in specifications.
Row names	Product qualities codes using six characters; the first three are RFG, the next two are quality codes, the last is either X for maximum or N for minimum; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. The quality coefficients of SSR reflect a reformulated gasoline that is to be blended with 7.8 percent ethanol and therefore has a lower octane and other qualities to accommodate the quality barrels delivered by ethanol.

TABLES (R)SST	***SUBSPEC TRG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing 5 transition years for changes in specifications.
Row names	Product qualities codes using six characters; the first three are TRG, the next two are quality codes, the last is either X for maximum or N for minimum; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. The quality coefficients of SST reflect a conventional gasoline that is to be blended with 7.8 percent ethanol and therefore has a lower octane and other qualities to accommodate the quality barrels delivered by ethanol.

TABLES (R)RFH	***SUBSPEC RFG QUALITY SPECIFICATIONS--PMM REGION (R)***
Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing 5 transition years for changes in specifications.

Row names	Product qualities codes using six characters; the first three are RFG, the next two are quality codes, the last is either X for maximum or N for minimum; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year.

TABLES (R)TRH ***SUBSPEC TRG QUALITY SPECIFICATIONS--PMM REGION (R)***

Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing 5 transition years for changes in specifications.
Row names	Product qualities codes using six characters; the first three are TRG, the next two are quality codes, the last is either X for maximum or N for minimum; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year.

TABLES (R)SSE ***SUBSPEC TRG QUALITY SPECIFICATIONS--PMM REGION (R)***

Column names	Five columns: Y1,Y2,Y3,Y4,Y5--representing 5 transition years for changes in specifications.
Row names	Product qualities codes using six characters; the first three are TRG, the next two are quality codes, the last is either X for maximum or N for minimum; and a row YEAR to define the corresponding transition years.
Entries	Product quality specifications for each transition year. The quality coefficients of SSE reflect a 10 percent ethanol blend.

TABLE GCB ***GASOLINE QUALITIES (EX OCTANE)***

Column names	Quality codes
Row names	Intermediate product codes
Entries	Blending values

TABLE GCC ***GASOLINE COMPONENT USAGE CONTROL***

Column names	Finished product codes.
Row names	Intermediate stream codes
Entries	A non-blank entry indicates that the intermediate is allowed as a component to the finished blend.

TABLE GASGROUP ***GAS GROUP CLASSIFICATION***

Column names	One column, TEXT(1).
Row names	Three character stream code matching those in ***Table GCB***.
Entries	Three character gas group classification: G00-G12.

TABLE GSLUTI	***GASOLINE BLEND UTILITIES***
Column names	Utility, electricity, KWh.
Row names	Three character gasoline type or blend ID.
Entries	KWh per barrel of feed.
TABLE MCO	***GASOLINE COMPONENT OCTANE RATINGS***
Column names	Eight columns, R00, R05, R15, R30, M00, M05, M15, M30 of which the PMM model uses just two, R00 and M00 (lead-free research and motor octanes)
Row names	Intermediate stream gasoline component codes
Entries	Base research and motor octane blending numbers for each component at four levels of lead.
TABLES (xxx)BV	***GASOLINE COMPONENT BONUS BLENDING VALUES***
Column names	Nine columns, R00, R05, R15, R30, M00, M05, M15, M30, TEL of which the PMM model uses just two, R00 and M00 (lead-free research and motor octanes)
Row names	Intermediate stream gasoline component codes
Entries	Bonus research and motor octane blending numbers for each component at four levels of lead. Non-zero entries are added to the base octanes from ***Table MCO*** and used in the relevant gasoline blend. Since the **PMM** model reduces all gasoline grades to an equivalent lead-free basis, the only entries relevant in these "BV" tables are those under unleaded ROO and MOO octane columns.

(xxx = UNC and RFM (representing TRG and RFG, respectively).)

(distblnd)

TABLES Q(R)DFO	***REGIONAL DISTILLATE/FUEL OIL SPECIFICATIONS--PMM REFINERY REGION (R)***
Column names	Finished distillate fuel oil codes; Distillates JTA, N2H, DSL and residual fuel oils N6I,N6B.
Row names	Two character quality codes, followed by X (maximum) or N (minimum).
Entries	Columns contain specification levels for the corresponding qualities.
TABLE DCB	***DISTILLATE QUALITIES (EX OCTANE)***
Column names	Quality codes
Row names	Intermediate stream codes
Entries	Blending values

TABLE DCC	***DISTILLATE COMPONENT USAGE CONTROL***
Column names	Finished product codes.
Row names	Intermediate stream codes
Entries	A non-blank entry indicates that the intermediate is allowed as a component to the finished blend.
TABLE DFOUTI	***DISTILLATE BLENDING UTILITIES***
Column names	One column, STM, steam.
Row names	Five distillate fuel oil products: JTA, N2H, DSL, N6I, N6B.
Entries	Steam use per barrel of feed (lbs/bbl).

(recipes)

TABLE RCP	***RECIPE BLEND CONTROL***
Column names	Three columns, A, CST, and STM, plus intermediate stream codes.
Row names	Finished product codes followed by a number. The intention is to provide for different recipes for a given product. The row ending in a zero must be present.
Entries	A non-blank entry in column A activates the corresponding blend. Column CST contains any cost met in making the blend, e.g. TEL cost for production of aviation gasoline. The remaining columns contain the volume fractions of the components making up the blend.
TABLE RCPEIA	***RECIPE BLEND CONTROL***
Column names	Seven columns, A, CST, and five selected product streams (JTA, N2H, SLP, CKH, CKL).
Row names	Special products: salable sulfur, low and high sulfur coke.
Entries	A non-blank entry in column A activates the corresponding blend. Column CST contains any cost met in making the blend, e.g. TEL cost for production of aviation gasoline. The remaining columns contain the volume fractions of the components making up the blend (including unit conversions).

(splash)

TABLES BLNSP(D)	***RECIPE BLENDING FOR KEROSENE AND RESIDUAL OIL TO UTILITIES--CENSUS DIVISION (D)***
Column names	Three columns, KER, N67, and N68.
Row names	Stream codes for components of each blend and blended product codes.

Entries	Volume fraction of each component in final blends.

TABLES BLOX(D)YXX RECIPE BLENDS FOR HIGH OXYGEN GASOLINES IN CENSUS DIVISION (D)

Column names	Six columns, E85, M85, TRH, RFH, RFG, and TRG.
Row names	Stream codes for components of each blend and blended product codes plus OBJ row.
Entries	Volume fraction of each component in final blends. Row OBJ contains tax credit for blends.

TABLE HOXETH ETHANOL RECIPES FOR SPLASH BLENDING

Column names	Four columns, TRH, RFH, RFG, TRG.
Row names	Gasoline blend streams.
Entries	Consumption and yield fractions for ethanol blending streams.

TABLE XETH OXYGEN CONTENT OF ETHANOL

Column names	One column, PO.
Row names	One row, XETH.
Entries	Volume percent oxygen for ethanol.

TABLE SCB OXYGEN CONTENT OF OXYGENATES

Column names	One column, PO.
Row names	Three character oxygenate stream codes (ETB,MTB,TAE,TAM,THE,THM).
Entries	Volume percent oxygen for oxygenate streams.

(demand)

TABLE CKSMIX SALABLE COKE RECIPES

Column names	Two columns, CKL and CKH for low sulfur and high sulfur coke, respectively.
Row names	Coke stream codes (CKL, CKH) and product coke (COK); OBJ is scaled for selling price for coke.
Entries	Price ratio for coke (to be multiplied by WOP). Conversion from tons to bbls, and 1.0 coefficient for material balance.

(fuelmix)

TABLE GROUP	***FUEL MIX COMPONENTS***
Column names	One column, DUMMY.
Row names	Six character code, consisting of a three character intermediate stream code and a three character fuel stream code.
Entries	No entry.

A.3.9 Refining Technology

The tables described in this section are essential to the representation of refining technology. All the tables are named (uns), representing the refining technology processing unit. The Column names represent modes of operation. The Row names represent refinery process input and output streams (intermediate streams), policy (OVC, LOS, etc.) cost information, and utility (KWH,STM) consumption. The table entries are volume fractions (bbl Output/bbl Input) for intermediate streams; costs ($/bbl) for policy information; and utility consumption rates (kWh/bbl and lb/bbl) for electricity and steam, respectively. Most of the following tables described in this section are located in the file named (**refproc**). The cogeneration refinery processing unit data is located in the file named (**cogener**).

(refproc)

TABLE VCU CRUDE VACUUM DISTILLATION UNIT

Vacuum distillation refinery process unit. This unit separates atmospheric distillation tower bottoms into the following fractions:

- Heavy diesel cut (650-690 degrees Fahrenheit), according to sulfur content, pour point and cetane index
- Light gas oil (690-800 degrees Fahrenheit), according to sulfur content
- Heavy gas oil (800-1050 degrees Fahrenheit), according to sulfur content
- Vacuum residuum (1050 + degrees Fahrenheit), according to sulfur content, with the high metal/asphaltene content residua being undercut below 1050 degrees Fahrenheit.

The atmospheric residua which feed the vacuum distillation unit tower are classified according to similar API gravity, sulfur content, viscosity, and gas oil content into 13 categories. These provide sufficient differentiation for the RYM regional model:

Table A3. Atmospheric Residual Oil Qualities

Stream Code	Atm Resid Sulfur	Atm Resid API
ARA	3.10	17.5
ARB	2.67	17.7
ARC	1.54	19.9
ARD	1.30	12.4
ARE	0.87	19.3
ARF	0.34	25.4
ARG	0.32	22.8
ARH	2.70	14.0
ARI	0.32	17.1
ARJ	1.22	21.7
ARK	0.70	21.2
ARL	4.54	8.2
ARM	3.92	15.0

Data sources are based on in-house EnSys data and EnSys calculations and estimates.

TABLE KRD DELAYED COKER

Delayed coking of vacuum residua and FCC decant oil streams produce petroleum market coke and lighter products. Care has been taken to weight balance the yields and to match both low and high sulfur coke productions against actual regional makes. The naphtha fractions produced are of necessity stabilized and reformed (the annualized cost of stabilizing the C5-175 fraction is included in the OVC unit operating cost row). The middle distillates require stabilization and hydrotreating before blending to distillate fuels. The coker gas oil produced may be desulfurized and routed either to FCC feed or residual fuel oil blending.

Data sources are in-house EnSys data gathered from a variety of published sources, including J. H. Gary and G.E. Handwerk, *"Petroleum Refining Technology and Economics"*, 1975 and the EIA RYM model data as provided to ORNL by EIA and thereafter to EnSys.

TABLE KRF FLUID AND FLEXI COKER

Fluid coking of vacuum residua to produce coke and lighter products. Care has been taken to weight balance the yields and to match both low and high sulfur coke productions against actual regional makes. The naphtha fractions produced are of necessity stabilized and reformed (the annualized cost of stabilizing the C5-175 fraction is included in the OVC unit operating cost row). The middle distillates require stabilization and hydrotreating before blending to distillate fuels. The coker gas oil produced may be desulfurized and routed either to FCC feed or residual fuel oil blending.

Flexicoking is also represented in this program module, reflecting the gasification of the coke produced to fuel gas.

The data sources include the following:

> Busch, R. A. et al, *"Flexicoking + Hydrotreating Processes for Quality Products"*, presented at the AIChE Spring Meeting, April 1979.
>
> Blaser, D. E. et al, *"Fluid Coking/Flexicoking, a Flexible Process for Upgrading Heavy Crudes"*, Exxon Research and Engineering Company, October 26, 1978.

TABLE SDA PROPANE DE-ASPHALTER

Residua produced by the vacuum distillation unit are solvent extracted to produce asphalt, FCC feed, and heavy fuel oil blending components. Data sources are in-house EnSys data gathered from a variety of published sources.

Because of the limited number of vacuum residua depicted in the model, it is not possible for this unit to convert one residuum into another, plus gas oil and retain reasonable volume, weight and sulfur balances. Accordingly, the model activities represent only the partial conversion of one residuum into another.

TABLE VBR VISBREAKER

Visbreaking of vacuum residua to produce lowered viscosity residual blendstocks. Visbreaking is a mild thermal cracking process and produces a proportion of lighter products.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data. The range of potential feeds has been extended by EnSys.

TABLE NDS NAPHTHA HYDROTREATER

Hydrotreating of various refinery naphtha streams prior to reforming or blending with naphtha sales. The data source is the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data.

TABLE DDS HEAVY NAPHTHA, KEROSENE, AND MIDDLE AND HEAVY DISTILLATE DESULFURIZER

This unit represents the desulfurization of a broad and comprehensive set of refinery streams, ranging from 325 IBP to 690 EP degrees Fahrenheit. Various degrees of desulfurization intensity are also represented, ranging from normal (90 percent desulfurization) to the ultra low sulfur mode for blending to meet 0.05 weight percent diesel fuel. The different modes are also reflected through the use of the CAP row, with coefficients ranging from 0.8 to 3.33 to represent the different catalyst to oil ratios required to achieve different degrees of desulfurization. The increase in the CAP coefficients is tantamount to forcing a reduction in unit throughput and space velocity to reduce the sulfur level of the product stream.

High and medium and low sulfur (adequate for conventional, but not ultra-low sulfur fuels) feeds are included in ***Table DDS***. These include virgin heavy naphtha; light and heavy kerosene fractions; diesel and Number 2 fuel oil streams; FCC light cycle oil streams, reflecting different FCC conversion levels and gas oil feed sulfur levels; middle distillate furfural extraction unit raffinates; de-waxed diesel fractions; and select JP8-X and JP11 cuts from specialty naphthenic crude oils used for producing high density jet fuels.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and EnSys analysis of published sources. These include:

Shih, S. S. et al, *"Deep Desulfurization of Distillate Components"*, Paper 264B presented at the AIChE Fall Meeting, November 1990.

McCulloch, D. C. et al, *"Higher Severity Diesel Hydrotreating"*, Paper AM-87-58 presented at the NPRA Annual Meeting, March 1987.

Johnson, A. D., *"Study Shows Marginal Gains from Hydrotreating"*, Oil & Gas Journal, May 30, 1983, p.78.

Yoes, J. R. and Asim, M. Y., *"Confronting New Challenges in Distillate Hydrotreating"*, Paper AM-87-59 presented at the NPRA Annual Meeting, March 1987.

TABLE FDS GAS OIL DESULFURIZER/MILD HYDRO-CRACKER

This unit represents the desulfurization of light and heavy gas oils, including coker gas oil, to produce hydro-treated gas oils for FCC feed and heavy fuel oil blending. A light hydrocracking mode is also represented to produce a very low sulfur content gas oil for the purpose of removing sulfur from light and heavy catalytic gasolines in order to produce reformulated gasoline at the 50 ppm sulfur level.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data. The mild gas oil hydrocracking data were obtained from:

Belt, B. A., *"New Approaches to FCC Hydrotreating"*, Paper 44C presented at the AIChE Spring Meeting, March 1990.

TABLE RDS RESIDUUM DESULFURIZER

This unit represents the desulfurization of vacuum and atmospheric residua, gas oils and asphalt. Two levels of desulfurization are represented: 77 percent and 85 percent desulfurization. The heavy products are generally in the 0.5- to 1.0-weight percent sulfur content level and may be used as low sulfur residual fuel oil blendstocks, or to provide the FCC with feed for residuum cracking.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys, in-house EnSys data, and other published sources, including the following:

> Billon, A. et al, *"Hyvahl F and T Processes for High Conversion and Deep Refining of Residues"*, Paper AM-88-62 presented at the NPRA Annual Meeting, March 1988.

TABLE LUB LUBE OIL AND WAX PRODUCTION

This is a rather simplified representation which transfers 800-1050 degree Fahrenheit hydrofined gas oil and paraffin base gas oil to combined lube oil and wax sales. The unit contains the estimated fuel, power, steam, and operating cost requirements to produce these products.

Data sources are the EIA RYM model data.

TABLE HCR DISTILLATE HYDROCRACKER

This process unit hydrocracks a range of distillates to produce either predominantly light, medium, and heavy naphtha for gasoline blending and reformer feed, or distillate for jet fuel and middle distillate products (particularly low sulfur blends). These two modes of operation require large quantities of hydrogen, from 1800 to 3600 cf/bbl of feed, depending on the feedstock and severity of the operation. The primary feeds are light and heavy gas oils:

LGP, LGL,	paraffinic, low, medium, and high sulfur light gas oils,
LGM, and LGH:	690 to 800 degrees Fahrenheit.
HGP, HGL,	paraffinic, low, medium, and high sulfur heavy gas oils,
HGM, and HGH:	800 to 1050 degrees Fahrenheit.
LC6:	high aromatic content, high sulfur light cycle oil

The lighter virgin distillates may also be routed to hydrocracker feed. These streams are gathered into feeds HFL and HFH in ***Table TRS*** as follows:

DSL B(550-650)LP/LC/LS	CRACKER FD LO S	DLLHFL
DSL B(550-650)LP/HC/LS	CRACKER FD LO S	DHLHFL
DSL B(550-650)LP/HC/HS	CRACKER FD HI S	DHHHFH
DSL B(550-650)HP/LC/LS	CRACKER FD LO S	2LLHFL
DSL B(550-650)HP/HC/LS	CRACKER FD LO S	2HLHFL
DSL C(650-690)LP/LC/LS	CRACKER FD LO S	6LLHFL

DSL C(650-690)LP/HC/LS	CRACKER FD LO S	6HLHFL
DSL C(650-690)HP/LC/LS	CRACKER FD LO S	7LLHFL
DSL C(650-690)HP/HC/LS	CRACKER FD LO S	7HLHFL
DIST(550-650) HS/LM	CRACKER FEED	DHLHFH
DIST(650-690) HS/LM	CRACKER FEED	6HLHFH
LGO FD(690-800) PFFN	CRACKER FD LO S	LGPHFL
LGO FD(690-800) LO S	CRACKER FD LO S	LGLHFL
LGO FD(690-800) HI S	CRACKER FD HI S	LGHHFH
COKER DIST (375-620)	CRACKER FD HI S	CKDHFH
COKER DIST (375-570)	CRACKER FD HI S	CCLHFH
COKER DIST (575-620)	CRACKER FD HI S	CCHHFH
CKR DIST RAFFINATE	CRACKER FD HI S	CLRHFH
CKR DIST EXTRACT	CRACKER FD HI S	CLEHFH

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data. Published sources include the following:

Alcock, L. et al, *"BP Hydrocracks For Mid Distillates"*, Oil & Gas Journal, July 6, 1974, p.102.

J. H. Gary and G.E. Handwerk, *"Petroleum Refining Technology and Economics"*, 1975.

Logwinuk, A. K., *"The ART Process Offers Increased Refinery Flexibility"*, Petroleum Review, October 1985, p.41.

TABLE HCV RESIDUUM HYDROCRACKER

This unit hydrocracks a range of vacuum residua producing a synthetic crude containing the full range of streams from light gas oils to gas oil and bottoms fractions. Hydrogen consumption is of the order of 1500 cf/bbl net residuum feed. The feedstocks are vacuum resids produced by the vacuum distillation unit VCU and subsequently condensed to a smaller set of streams in ***Table TRS***:

VAC RES	V HI SUL(3.8)	RSV
VAC RES	HI SUL (2.3)	RSH
VAC RES	INT SUL (1.5)	RSM
VAC RES	LO SUL (0.9)	RSI
VAC RES	VLO SUL (0.5) RSL	

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data. Published sources include:

Seko, M. et al, *"Super Oil Cracking (SOC) Process for Upgrading Vacuum Residues"*, Paper AM-88-61 presented at the NPRA Annual Meeting, March 1988.

Suchanek, A.J. and Christian, B. R., *"New Diversity Shown for the ART Process"*, Paper AM-88-74 presented at the NPRA Annual Meeting, March 1988.

Boening, R.E. et al, *"Recent Data on Resid Hydrocracker", Hydrocarbon Processing"*, September 1987, p.59.

TABLE HCN NAPHTHA HYDROCRACKER

This unit consumes of the order of 1500 cf/bbl of hydrogen to hydrocrack naphthas. The naphthas are hydrocracked to produce primarily propane, isobutane, and normal butane. While this process has a history of commercial operation, it is not in wide-spread use. However, the advent of reformulated gasoline has renewed interest because the naphtha hydocracker functions to supply feed to alkylation and oxygenate process units. The propane may be de-hydrogenated to produce alkylate feed or the ether DIPE, the isobutane may be used directly for alkylation plant feed or de-hydrogenated to produce isobutylene to make MTBE or ETBE and the normal butane may be isomerized to produce isobutane. An additional fit with reformulated gasoline production is the fact that naphtha is subtracted from the reformer feed, thus lowering the quantities of benzene and aromatics that are produced.

Data sources are based on in-house EnSys data, calculations and estimates.

TABLE TCG THERMAL CRACKER-LIGHT GAS STREAMS
TABLE TCN THERMAL CRACKER-(250-375) NAPHTHA STREAMS
TABLE TCV THERMAL CRACKER-DESULFURIZED VACUUM GAS OIL STREAMS

The above process units are olefin plant petrochemical units which are characteristic of petrochemical plant operations. They are included in the model because they have potential relevance to the production of reformulated gasoline since they produce light olefins (ethylene, propylene and iso and normal butylenes) for alkylation plant feed and (the isobutylene) for MTBE and ETBE plant feed. They can also be used directly in any representation of the petro-chemical sector via the **PMM** "oxy-refinery" feature.

Process unit TCG may use ethane, propane or iso or normal butanes as feedstocks.

Process unit TCN consumes reformer feed naphtha (which would otherwise produce high aromatics content reformate).

Process unit TCV consumes desulfurized light and heavy gas oils produced by process unit FDS.

Data sources are based on published data:

Zdonik, S. B. and Meilun, E. C., *"Olefin Feedstock and Product Flexibility"*, Chemical Engineering Progress, September 1983.

Barendrect, S. et al, *"BUTACRACKING - Steam Cracking For Butane Upgrading"*, Paper 26E, presented at the AIChE Spring Meeting, April 1991.

TABLE JPS JET FUEL CUT POINT ADJUSTMENT

This unit adjusts the cut point of the 375 to 500 degree Fahrenheit atmospheric tower kerosene cut to a 470-degree endpoint cut in order to make the freezing point specification for JP-8 and Jet A/A-1 jet fuels in the optimal manner conforming to industry practice. This can be regarded as a "pseudo-unit" corresponding to an atmospheric tower cut point adjustment when making a jet fuel run, or as a real side-stream fractionator. Data sources are based on in-house EnSys data, calculations, and estimates.

TABLE JFP LIGHT CYCLE OIL/COKER DISTILLATE PRE-FRACTIONATION

This is a specialty unit which prepares cracked aromatic streams for furfural unit extraction and hydrogenation (units FEX and HDN) for the production of high density jet fuels. High density jet fuels are experimental fuels which increase the flight range of volume limited aircraft. The cuts are 70 Overhead/30 Bottoms for LCO and 80 Overhead/20 Bottoms for coker distillate. The fractionated streams may also be routed to conventional distillate products and heavy fuel oils, thus increasing blending flexibility.

Data sources are based on in-house EnSys data, calculations and estimates.

TABLE SYD DISTILLATE DEEP HYDROTREATER

(used to be identified as DHT prior to *AEO01*)

This process hydrogenates middle distillate aromatics and achieves deep desulfurization (to levels beyond those available with conventional distillate desulfurization, see *Table DDS*). Potential feeds include kerosene, diesel, and light cycle oils, covering the boiling range from 375 to 650 degrees Fahrenheit. The deep hydrotreating process can be used to raise jet fuel smoke point, raise diesel fuel cetane number, and produce ultra low sulfur/aromatics fuels (less than 0.05 percent sulfur and less than 10 percent aromatics content). Conventional distillate desulfurization units, on the other hand, are generally capable of reducing the aromatics content by only 1 to 2 percent aromatics. This process is an alternative to middle distillate furfural extraction, but avoids the problem of aromatics disposition. However, hydrogen consumption is high, from 750 to 900 cf/bbl feed for virgin distillates and from 1100 to 2100 cf/bbl for the more aromatic FCC cycle oils.

This process may be linked to the production of reformulated gasoline since some reformulated gasoline production schemes involve very high conversion FCC operations, which in turn increase the aromaticity of the light cycle oils produced. Deep distillate hydrotreating makes it possible to more easily produce specification diesel fuel under these circumstances, without downgrading cycle oils to heavy residual fuel oil.

Data sources are in-house EnSys data and published data, including:

Suchanek, A.J. and Hamilton, G. L., *"Diesel by SYNSAT - Low Pressure/Low Cost/Low Aromatics"*, Paper AM-91-35 presented at the NPRA Annual Meeting, March 1991.

Nash, R.M., *"Meeting the Challenge of Low Aromatics Diesel"*, Paper AM-89-29 presented at the NPRA Annual Meeting, March 1989.

TABLE FEX DISTILLATE FURFURAL EXTRACTION

This process extracts aromatics from distillate with the aromatics being concentrated in the furfural phase. Furfural extraction also lowers the sulfur content of the treated raffinate. Potential feeds include kerosene, diesel fractions, light cycle oils, and coker distillates, covering the boiling range from 375 to 690 degrees Fahrenheit. The reduction in distillate aromatics content can be used to raise jet fuel smoke point and/or raise diesel fuel cetane number and produce ultra low aromatics fuels (less than 10 percent aromatics content). Conventional desulfurization units, on the other hand, are generally capable of reducing the aromatics content by only 1 to 2 percent.

This process is an alternative to middle distillate deep hydrotreating, but necessitates the disposition of the aromatics produced, generally by attempting to dump to other distillates, or by using them to reduce the viscosity and perhaps the sulfur content of heavy residual fuel oils. However, the significant hydrogen consumption associated with deep hydrotreating is avoided, ranging from 750 to 900 cf/bbl feed for virgin distillates and from 1100 to 2100 cf/bbl for the more aromatic FCC cycle oils.

The furfural extraction unit is also used to extract aromatics from virgin distillate streams, FCC cycle oil and coker distillate overhead cuts prior to the hydrogenation of the aromatic extracts to produce distillate range naphthenes. The naphthenes are blended to produce experimental high density jet fuels.

Data sources are based on EnSys calculations and estimates and in-house EnSys data. Published data sources include:

Refinery Handbook, Furfural Extraction of Gas Oils, Hydrocarbon Processing, September 1982, p.183.

Benham, A. L. et al, *"REDEX Process Extracts Aromatics"*, Hydrocarbon Processing, September 1967, p.135.

TABLE HDN HIGH DENSITY JET FUEL HYDROPROCESSING

This unit hydroprocesses several types of streams to produce highly naphthenic blending components for high density jet fuel. The feedstocks are:

- light pyrolysis fuel oil
- FCC light cycle oil 70 percent overhead cuts
- the corresponding light cycle oil furfural extracts
- coker distillate 80 percent overhead cuts
- the corresponding coker distillate furfural extracts
- the aromatic furfural unit extracts produced from virgin distillate streams, ranging from 375 to 500 degree Fahrenheit boiling range.

This unit employs severe processing conditions and the fuel, power, and steam costs are high. Hydrogen consumption can reach 2400 cf/bbl for the virgin distillate stream aromatic extracts and 3500 cf/bbl for the other highly refractory streams.

The former Soviet Union has utilized high density jet fuels to increase the mission range of volume-limited military jet aircraft. Data were gathered and pieced together from several published Russian and other foreign sources with the help of ORNL. Other published sources used include:

Korosi, A. et al, *"Hydroprocessing of Light Pyrolysis Fuel Oil for Kerosene Jet Fuel"*, Technical Report AFWAL-TR-80-2012, February 1980.

Hall, L. W., *"Production of Jet Fuel Samples from Light Cycle and Light Pyrolysis Oil"*, Technical Report AFWAL-TR-87-2001, March 1987.

TABLE DEW CATALYTIC GAS OIL DEWAXING

This is a catalytic process based on the Mobil process for converting the paraffin wax components in intermediate and heavy middle distillate streams in order to meet the freezing and pour point specifications for low pour distillate and heavy fuel oils. This process is an alternative to solvent dewaxing, where finished refinery waxes are sold. It may accompany or replace the use of pour point depressants.

This unit feeds high pour refinery streams covering the range of 550 to 690 degrees Fahrenheit, where the high boiling paraffin waxes are concentrated. Approximately 200 cf/bbl of hydrogen is consumed.

Published sources include:

Collins, J. M. and Unzelman, G. H., *"Alternatives Available to Meet Diesel Cetane Quality Challenge"*, Oil & Gas Journal, May 30, 1983, p.71.

TABLE RFH REFORMER-SEMI REGENERATIVE-450 PSI REACTOR
TABLE RFL REFORMER-SEMI REGEN/CYCLIC-200 PSI REACTOR
TABLE RFC CONTINUOUS REFORMER LOW PRESS./HIGH DENSITY BIMET.CATALYST

Naphtha reforming refinery process units. These individual key processes represent the different stages of reformer technology development. Paraffinic, naphthenic, and intermediate naphtha feeds are represented to produce reformates spanning the range of 80 to 105 clear research octane number. The low end of the reforming severity range is geared to accommodating the lower aromatic content of reformulated gasoline; the high end represents the limit of current reforming technology. The effect of low through high reforming severity on reformer throughput capacity is represented in row CAP, with coefficients ranging from 0.9 to 1.2, with an entry of 1.0 representing 95-100 RONC reformate production.

The severity rows SVH, SVL and SVC contain the reformate RONC octane. Several operating mode limitation rows are also available in the reformer tables to link to ***Tables (R)POL*** constraints:

L00, H00 to limit maximum 100 RONC reforming severity
C05, L05, H05 to limit maximum 105 RONC reforming severity

MXU to limit the proportion of UOP type R-62 high density bimetallic reforming catalyst
RCU to limit very low pressure and low benzene advanced modes on the continuous reformer (RFC).

The specific reformer feed streams represented include the following:

158-175 degrees Fahrenheit	very light virgin naphtha
175-250 degrees Fahrenheit	light virgin naphtha
250-325 degrees Fahrenheit	intermediate virgin naphtha
325-375 degrees Fahrenheit	heavy virgin naphtha
250-400 degrees Fahrenheit	heavy FCC gasoline
175-375 degrees Fahrenheit	coker naphtha
250-325 degrees Fahrenheit	heavy hydrocrackate
215-250 degrees Fahrenheit	light virgin naphtha, prefractionated to remove benzene precursors.

The capability to reform 325-375 virgin naphtha feed stock is not immediately apparent in the reformer data tables because it is represented in ***Table TRS*** by combining naphtha desulfurizer feeds, namely:

H N/L J(325-375) P/LF	NAPHTHA(250-325) P	JPLNPP
H N/L J(325-375) I/LF	NAPHTHA(250-325) I	JILNPI
H N/L J(325-375) N/LF	NAPHTHA(250-325) N	JNLNPN
H N/L J(325-375) P/HF	NAPHTHA(250-325) P	JPHNPP
H N/L J(325-375) I/HF	NAPHTHA(250-325) I	JIHNPI
H N/L J(325-375) N/HF	NAPHTHA(250-325) N	JNHNPN

The reformer products include hydrogen (95 percent purity), fuel gas, LPG, and full boiling range reformate.

The gradation of reformate feed cut ranges is consistent with (a) maximizing reformer feed, e.g. for foreign regions where gasoline demand is high, but also (b) controlling benzene content of reformate for use in reformulated gasoline. This latter can be achieved in the model by eliminating the 158-175 fraction and, if necessary, the 175-250 fractions from reformer feed. In addition, the model now has the option to pre-fractionate light naphtha at 215 degrees Fahrenheit to produce feedstock to the RFC unit for very low benzene reformate production. (See ***Table GCB*** for comparison of reformate benzene contents.)

Altogether, the PMM model contains several methods for benzene reduction or removal:

1. Reformer feed pre-fractionation as discussed above,
2. Reformate splitting (***Table RES***)
3. Extraction of benzene (for sale) from reformate aromatics (***Table ARP***)
4. Very low pressure reformate operation (***Table RFC***)
5. Alkylation of benzene in reformate (***Table ALM***).

RFC unit ultra-low pressure reforming, at 90 psi, reduces the reformate benzene content by approximately 30 percent for reformulated gasoline production. Commercial plant data have not yet been obtained to verify the model reforming yields.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data and published data compared and gathered from a variety of sources. Sources include:

> *"UOP Process Solutions for Reformulated Gasoline"*, Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.
>
> van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.
>
> Jones, P. *"The Conversion Refinery: The Catalytic Magic Wand"*, Petroleum Review, May 1987.
>
> McClung, R. G. and Novak, W. J., *"Improve Reformer Operation with Trace Sulfur Removal"*, Paper AM-87-47 presented at the NPRA Annual Meeting, March 1987.
>
> Gerritsen, Dr. L. A., *"Catalytic Reforming of Heart Cut FCC Naphthas"*, Paper AM-85-56 presented at the NPRA Annual Meeting, March 1985.

TABLE SPL NAPHTHA SPLITTER

This is a feed preparation unit which fractionates light naphtha for reformer feed. C5-175 degrees Fahrenheit straight run gasoline is fractionated to produce C5-158 light gasoline for gasoline blending and 158-175 degrees Fahrenheit light naphtha for reformer feed. This represents the light end range of currently feasible reformer feed. The splitter now also enables splitting 175-250 degrees Fahrenheit light naphtha at 215 degrees Fahrenheit to produce a 175-215 degrees Fahrenheit light naphtha and a 215-250 degrees Fahrenheit low benzene reformer feedstock.

The fractionated light naphthas produced may also be blended to JP4 military jet fuel and to naphtha sales.

Data sources are in-house EnSys data and the following:

> *"UOP Process Solutions for Reformulated Gasoline"*, Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.
>
> van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.

TABLE RES REFORMATE SPLITTER (not used)

This unit splits the reformates produced from 250-375 degrees Fahrenheit intermediate/heavy naphtha into an overhead and a bottoms cut. These fractions may be separately blended into conventional and reformulated

gasolines to aid in meeting reformulated gasoline specifications. The aromatics concentrate in the bottoms cut and the benzene in the overhead.
Data sources are in-house EnSys data and EnSys calculations, estimates and published data, including:

> van Broekhoven, E. B. et al, *"On the Reduction of Benzene in Reformate"*, Paper 28B presented at the AIChE Spring Meeting, March 1990.
>
> *"UOP Process Solutions for Reformulated Gasoline"*, Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE ARP AROMATICS EXTRACTION

This unit employs solvent extraction of reformate and reformate fractions to produce benzene, toluene, and xylene (BTX) aromatics for sale, and light and heavy raffinates for gasoline and jet/distillate fuel blending. All of the reformates produced in the semi-regenerative, continuous and cyclic reformers are potential unit feeds, along with their overhead and bottoms cuts produced in the reformate splitter.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data and EnSys calculations and estimates.

TABLE ALM ALKYMAX (not used)

This unit is patterned after the UOP Alkymax process for alkylating benzene with C_2 and C_3 olefins (ethylene and propylene) to produce higher boiling aromatics. The reformates produced from 158-250 light/intermediate naphtha are reacted with fuel gas containing ethylene or with propylene to produce an essentially benzene-free reformate. These reformates are then blended to meet reformulated gasoline benzene specification. *(Note: the aromatics concentration in the gasoline blend is hardly altered.)*
Data sources include the following:

> B. M. Wood et al, *"Alkylate Aromatics in the Gasoline via the UOP ALKYMAX Process"*, Copyright 1990, provided by UOP to ORNL.
>
> *"UOP Process Solutions for Reformulated Gasoline"*, Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE CYC CYCLAR

Cyclar refinery process unit based on the UOP cyclar process to cyclarize propane and butane to produce BTX. A fractionated benzene stream is produced along with a TX (toluene, xylene) stream designated as cyclar gasoline. This is a de-hydrogenation process which produces approximately 2000 cf/bbl feed of hydrogen.

The data sources include the following:

Anderson, R. F. et al, *"Cyclar - One Step Processing of LPG to Aromatics and Hydrogen"*, Paper 83D presented at the AIChE Spring Meeting, March 1985.

TABLE FCC FLUID CATALYTIC CRACKER

This key process unit is capable of catalytically cracking gas oil, light gas oil, distillate and residua streams to produce light ends, FCC gasoline, light cycle oil (distillate) and decant oil (resid). The primary feeds represented are:

Feed stream	Description
HGP:	paraffinic low sulfur gas oil (800-1050 degrees Fahrenheit)
HGL:	low sulfur gas oil (800-1050 degrees Fahrenheit)
HGM:	medium sulfur gas oil (800-1050 degrees Fahrenheit)
HGH:	high sulfur gas oil (800-1050 degrees Fahrenheit)
GOH:	hydrofined gas oil (800-1050 degrees Fahrenheit)
GOU:	hydrofined gas oil (800-1050 degrees Fahrenheit) ultra low sulfur
DFF:	distillate feed (550-690 degrees Fahrenheit)
DHK:	desulfurized atmospheric residuum (1050 degrees Fahrenheit +). Produced by unit RDS.
HGX:	gas oil raffinate produced by propane solvent de-asphalting
Atmospheric Residua:	several residua of sufficiently low asphalt and metals content (which tend to be the lower sulfur content residua) to conform to current FCC technology limitations.

In order to contain the already large number of FCC feed vectors, several streams are composited into the above primary feeds in ***Table TRS*** as listed below:

DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6LLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6HLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	7LLHGL
DSL C(650-690) PFFN	HGO FD(800-1050) PFFN	7HLLGP
COKER GAS OIL	HGO FD(800-1050) HI S N	CGOHGH
LGO FD(690-800) HI S N	HGO FD(800-1050) HI S N	LGHHGH
LGO FD(690 800) MD S N	HGO FD(800-1050) MD S N	LGMHGM
LGO FD(690-800) LO S N	HGO FD(800-1050) LO S N	LGLHGL
LGO FD(690-800) PFFN	HGO FD(800-1050) PFFN	LGPHGP
HGO FD(800 1050) LO S N	HYD G.O. LOS N UNH	HGLGOH
DIST LS/LM	DIST FCC FEED	DLLDFF
DSL B(550-650) HP/HC/LS	DIST FCC FEED	2HLDFF
DSL C(650-690) LP/HC/LS	H DIST FCC FEED	6HLDFF
DSL C(650-690) HP/HC/LS	H DIST FCC FEED	7HLDFF
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6LLHGL
DSL C(650-690) LO S N	HGO FD(800-1050) LO S N	6HLHGL

DSL C(650-690) LO S N HGO FD(800-1050) LO S N 7LLHGL

The FCC is characterized by several modes of operation and provision for activating restrictions on flexibility have been built in for constraining advanced FCC catalyst technology options and limiting over-optimization. The FCC representation now accurately equates FCC gasoline, distillates, and decant oil product sulfur with feed sulfur. The available options are:

Option	FCC gasoline codes	Constraints
Conventional zeolite catalyst		
high sulfur feed/product	FI6, FI7, FI8	MSD, MSR, FCR
med.sulfur feed/product	FC6, FC7, FC8	
low sulfur feed/product	FR6, FR7, FR8	
ultra-low sulfur feed/product	FQ6, FQ7, FQ8*	
High octane zeolite catalyst		
high sulfur feed/product	ZI6, ZI7, ZI8	MSD,MSR,MSZ
med.sulfur feed/product	ZC6, ZC7, ZC8	and FCR
low sulfur feed/product	ZR6, ZR7, ZR8	
ultra-low sulfur feed/product	RC6, RC7, RC8	
Low olefin content gasoline		
high sulfur feed/product	6ZI, 7ZI, 8ZI	MSZ
med.sulfur feed/product	6ZF, 7ZF, 8ZF	
low sulfur feed/product	6ZR, 7ZR, 8ZR	
ultra-low sulfur feed/product	6RF, 7RF, 8RF	
High light olefin yield		
high sulfur feed/product	85I	MSL
med.sulfur feed/product	85F	
low sulfur feed/product	85R	
ultra-low sulfur feed/product	85U	
Ultra-Low Sulfur Modes		FCU
All Modes		SVR

* *This feed sulfur/catalyst mode currently not activated, although FCC gasoline properties are held in* ***Table GCB****, etc.*

MSD and MSR refer to constraints on distillate/light gas oil and atmospheric residuum proportions. A value of "1" in the FCR row signals a residuum which is eligible for FCC residuum cracking, generally higher than 20 API, with the associated sulfur content lower than 0.7 percent. MSZ and MSL limit the proportion of specialty zeolite catalysts. The above references to low sulfur FCC gasoline refer to the production of catalytic gasolines generally suited to making reformulated gasoline at the 50-ppm level. FCU is the constraint on all ultra-low sulfur modes.

The low olefin content gasoline mode is directed at reducing the olefin content of reformulated gasoline by reducing the olefins in the catalytic gasoline, principally the light catalytic gasoline. This mode also lowers the octane somewhat and reduces the yield of C_5 and lighter olefins.

The high light-olefin yield operation takes a different approach to reformulated gasoline production and utilizes enhanced octane ZSM-5 catalyst with OHS additive to maximize the yield of light olefins to produce feedstocks for the oxygenate and alkylation refinery process units. The operating cost row OVC coefficient has been raised by $0.60/bbl of gas oil feed to account for the unit revamp and increased fractionation costs associated with this operation. This is a high conversion operation in the 80 to 85 percent range.

The FCC conversion range represented in the model is from 65 to 85 percent conversion to 430 degrees Fahrenheit- FCC gasoline. The SVR row may be used to constrain or report the overall conversion level. The light end yields contained in the model reflect an overall C3 recovery of 75 percent. Light cycle oil characterizations (qualities) are a function of conversion and FCC feed sulfur level. Decanted (clarified) oil characterizations are a function of sulfur level only:

LCO ULOW	0.05S 60P CONV LC7
LCO ULOW	0.05S 80P CONV LC8
LCO	0.25S 60P CONV LC1
LCO	0.25S 80P CONV LC2
LCO	0.85S 60P CONV LC3
LCO	0.85S 80P CONV LC4
LCO	2.00S 60P CONV LC5
LCO	2.00S 80P CONV LC6

CLARIFIED OIL	0.10 SUL	COX
CLARIFIED OIL	0.65 SUL	COL
CLARIFIED OIL	2.20 SUL	COM
CLARIFIED OIL	5.50 SUL	COH

The four levels of LCO and decant oil sulfur correspond to the four base levels of FCC feed sulfur, namely: 0.05 percent, 0.30 percent, 1.00 percent, 2.50 percent. Actual feeds may produce mixes of products depending upon actual feed sulfur level.

Weight fraction catalytic coke yields are contained in the model (row COK) and are set to be activated for checking the FCC weight balance and to provide input to any EIA type reports which contain FCC catalytic coke production.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data include the following published data:

"Fuels for Tomorrow", staff article, Oil & Gas Journal, June 18, 1990, p.52.

Chin, A. A. et al, *"FCC Cracking of Coker Gas Oils"*, Paper 91C presented at the AIChE Fall Meeting, November 1989

Humphries, A. et al, *"The Resid Challenge: FCC Catalyst Technology Update"*, Paper 70C presented at the AIChE Spring Meeting, April 1991.

Stokes G. M. et al, *"Reformulated Gasoline Will Change FCC Operations and Catalysts"*, Oil & Gas Journal, July 2, 1990, p.58.

Keyworth, D. A. and Reid, T. A., *"Octane Enhancement From LPG"*, Paper 5A presented at the AIChE Summer Meeting, August 1989.

"Innovative Improvements Highlight FCC's Past and Future", staff article, Oil & Gas Journal, January 8, 1990, p.33.

Deady, J. et al, *"Strategies For Reducing FCC Gasoline Sensitivity"*, Paper AM-89-13 presented at the NPRA Annual Meeting, March 1989.

Dwyer, F.G. et al, *"Octane Enhancement In FCC Via ZSM-5"*, Paper AM-87-63 presented at the NPRA Annual Meeting, March 1987.

Yanik, S. J. et al, *"A Novel Approach to Octane Enhancement Via FCC Catalysis"*, Paper AM-85-48 presented at the NPRA Annual Meeting, March 1985.

Krikorian, K. V. and Brice, J. C., *"FCC's Effect on Refinery Yields"*, Hydrocarbon Processing, September 1987, p.63.

TABLE FGS GASOLINE FRACTIONATION

This idealized unit, representing a probable series of distillation towers, fractionates:

- Whole catalytic gasoline specific to the different FCC unit operating modes
- Coker naphtha produced by the coker units KRD and KRF
- Purchased natural gasoline.

The whole FCC gasoline is fractionated to produce reactive amylenes for alkylation and oxygenate plant feed; normal amylene for gasoline blending, alkylation or hydrogenation; reactive hexylenes for oxygenate plant feed; normal hexylene for gasoline blending or hydrogenation; light catalytic gasoline, containing isopentane, normal pentane and iso- and normal hexanes plus the C_7 to 250 degrees Fahrenheit fractions; heavy catalytic gasoline (250 - 400 degrees Fahrenheit) for reformer feed and gasoline blending; and the front end of light cycle oil for distillate blending.

Coker naphtha (175 - 375 degrees Fahrenheit) is fractionated to produce iso-amylene, the other reactive amylenes and reactive hexylenes, and the remaining naphtha bottoms.

Natural gasoline is fractionated to produce iso and normal butane and light and medium naphtha cuts.

Data sources are in-house EnSys data, calculations and estimates supported by the following:

Keefer, P. and Masters, K., *"Ultimate C4/C5 Olefin Processing Scheme for Maximizing Reformulated Gasoline Production"*, Paper AM-91-50 presented at the NPRA Annual Meeting, March 1991.

Stokes G. M. et al, *"Reformulated Gasoline Will Change FCC Operations and Catalysts"*, Oil & Gas Journal, July 2, 1990, p.58.

TABLE ETS ETHYLENE CRYOGENIC FRACTIONATION

This unit distills ethylene from refinery gas for alkylation plant feed using cryogenic (low temperature technology). All feed and product streams are in barrels of fuel oil equivalents (bblFOE) and the saturate co-product PGS (ethane) is used for refinery fuel gas and to meet any refinery sales requirements.

Data sources are based on in-house EnSys data, calculations, and estimates.

TABLE OLE C_2-C_5 DE-HYDROGENATION ("OLEX")

This process unit dehydrogenates saturated C2/C3/C4 and IC5 refinery streams to produce on the order of 1500 cf/bbl of hydrogen per bbl of feed and the corresponding olefin streams for alkylation and oxygenate plant feeds. The propylene may be used for alkylation (or ether DIPE) plant feed and petrochemical sales, the normal butylene for alkylation plant feed, the isobutylene for MTBE/ETBE oxygenate production and alkylation plant feed and the isoamylene for TAME/TAEE oxygenate production and alkylation plant feed. This process is suited for reformulated gasoline production and aids in RVP reduction through removing butane and isopentane from the gasoline pool.

Data sources include the following:

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

Buonomo, G. et al, *"The Fluidized Bed Technology for Paraffins Dehydrogenation: Snam Progetti-Yarsintez Process"*, presented to DEWITT 1990 Petrochemical Review, Houston, Texas, March 27-29, 1990.

TABLE C4I BUTANE ISOMERIZATION

This unit isomerizes normal butane to produce isobutane. The isobutane may be used for alkylation plant feed and, potentially, for dehydrogenation to produce isobutylene for MTBE and ETBE production.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data.

TABLE C4S BUTENE TRANSFER PSEUDO-UNIT

This unit splits FCC and coker total butylenes into 70 percent normal butylene (C4E) and 30 percent isobutylene (I4E). No costs are attached to this unit because the total stream is normally fed to MTBE/ETBE plants without fractionation and only the isobutylene is consumed. The costs of processing the total butylene stream are included in the oxygenate plant costs.

The problem of reflecting the C4E/I4E split on alkylation plant costs is complex. The alkylate produced by normal butylene is approximately 4 RONC/MONC higher than that produced by isobutylene. Therefore, if the alkylation unit is preferentially consuming normal butylene from FCC/coker mixed butylenes, pre-fractionation costs should be attached to the alkylation plant for taking advantage of this option. However, if, as is often the case, oxygenate and alkylation units are both present in the LP solution (to produce reformulated gasoline), then the MTBE/ETBE unit is situated upstream of the alkylation unit so as to avoid the fractionation costs. The practice in this model is not to add additional alkylation plant feed pre-fractionation costs. This could cause over optimization (understate costs) for some cases.

Data sources are in-house EnSys data.

TABLE ETH,ETM OXYGENATE PRODUCTION

A process unit which consumes methanol or ethanol to produce a wide range of oxygenates. The olefin feeds and corresponding oxygenate products are:

Table A4. Oxygenate Products

Oxygenate Products				
Methanol Feed	Code	MTBE	TAME	THME
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X
Ethanol Feed	Code	ETBE	TAEE	THEE
Isobutylene	I4E	X		
Reactive Amylenes	R5E		X	
Reactive Hexylenes	R6E			X

The ***Tables (R)POL*** constraint NME can be used to constrain or eliminate all modes other than iso-butylene/MTBE.

The data for THME and THEE were estimated by EnSys, since there is little or no commercial experience to provide operating data. Other data sources include the following:

Bakas, S.T. et al, *"Production of Ethers from Field Butanes and Refinery Streams"*, presented at the AIChE Summer Meeting in San Diego, California, August 1990.

Prichard, *"Novel Catalyst Widens Octane Opportunities"*, NPRA Annual Meeting, San Antonio, Texas, March 29-31, 1987.

Miller, D. J., *"Ethyl Tertiary Butyl Ether (ETBE) Production"*, Paper 42B presented at the AIChE Summer Meeting, August 1989.

Des Courieres, J., *"The Gasoline Ethers: MTBE, ETBE, TAME & TAEE: Their Production"*, Paper 13A presented at the AIChE Summer Meeting, August 1990.

Chemical Engineering Progress, August 1991, p.16.

Unzelman, G. W., *"Future Role of Ethers in U. S. Gasoline"*, Paper AM-89-06 presented at the NPRA Annual Meeting, March 1989.

Refinery Handbook, Ethers, Hydrocarbon Processing, November 1990, p.126.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

Prichard, G., *"Novel Catalyst Widens Octane Opportunities"*, Paper AM-87-48 presented at the NPRA Annual Meeting, March 1987.

TABLE DIP PROPYLENE OXYGENATE PRODUCTION (not used)

This unit is modeled after a recently announced Mobil process which reacts propylene and water to produce a propylene ether (DIPE).

TABLE C24 DIMERIZATION OF ETHYLENE TO 1-BUTENE

This unit dimerizes ethylene to 1-butene for alkylation plant feed. It produces a small byproduct quantity of 1-hexene.

Data sources are based on in-house EnSys data, calculations, and estimates.

TABLE C4T ISOMERIZATION OF BUTENE-1 TO BUTENE-2

This unit isomerizes butene-1 to butene-2 for the purpose of improving alkylate quality and reducing the alkylation plant acid consumption. Approximately 13 cf/bbl of hydrogen is consumed to hydrogenate butadiene and reduce the mercaptan content. Alkylate octanes are increased 1.8 RONC and 0.8 MONC and alkylation plant operating costs are reduced by approximately 30 percent.

Data sources include the following:

Novalany, S. and McClung, R. G., *"Better Alky from Treated Olefins"*, Hydrocarbon Processing, September 1989, p.66.

TABLE ALK ALKYLATION

The isobutane sulfuric acid alkylation of the following feed streams is represented:

ETHYLENE (FOE)	C2E
PROPYLENE	UC3
MIXED BUTYLENES	UC4
N-BUTYLENE	C4E
TRT/ISOM BUTENE-2	T4E
ISOBUTYLENE	I4E
NORMAL AMYLENE	C5E
REACTIVE AMYLENE(ISO)	R5E

The feedstocks are reacted with iso-butane to produce alkylate product. The range of feedstocks has been extended because of the high significance of alkylates as reformulated gasoline blendstocks.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data. Published sources include:

Leonard, J. et al, *"What to do with Refinery Propylenes"*, Paper 5B, presented at the AIChE Summer Meeting, August 1989.

Masters, K. R., *"Alkylation's Role in Reformulated Gasoline"*, presented at the AIChE Spring Meeting, April 1991.

Masters, K. and Prohaska, E.A., *"Add MTBE Unit Ahead of Alkylation"*, Hydrocarbon Processing, August 1988, p.48.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE CPL CATALYTIC POLYMERIZATION

A process using solid phosphoric acid catalyst to polymerize propylene and butylenes to produce olefinic polymer gasoline.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data.

TABLE DIM DIMERSOL

A process using liquid phosphoric acid catalyst to polymerize propylene to produce dimer, which is lighter and higher in octane than olefinic polymer gasoline.

Data sources include:

> Leonard, J. et al, *"What to do with Refinery Propylenes"*, Paper 5B, presented at the AIChE Summer Meeting, August 1989.

TABLE H56 HYDROGENATION OF NORMAL AMYLENE AND HEXYLENE

This unit hydrogenates the normal C_5/C_6 olefins to produce low octane normal pentanes and hexanes for isomerizer unit feed, where the octanes are raised. Hydrogen consumptions are in the range of 1300-1500 cf/bbl.

Data sources are based on in-house EnSys data, calculations and estimates.

In an era of reformulated gasolines, this process provides a means of removing the reactive normal C_5 and C_6 olefins from the gasoline pool. As described elsewhere, the iso C_5 and C_6 olefins are likely to be dealt with by alkylation or etherification.

TABLE PHI PENTANE/HEXANE ISOMERIZATION

This is a partial recycle isomerizer (without molecular sieve) which produces isopentane- and isohexane-rich isomerates from the following potential feed streams:

NATURAL GASOLINE	NAT
LSR GASO(C5-175)ION	SRI
LSR GASO(C5-158)	GLI
NORMAL PENTANE	NC5
NORMAL HEXANE	NC6

Data sources are in-house EnSys data and the following sources:

> Schmidt, R. J. et al, *"Catalyst and Engineering Innovations Improve Isomerization Techniques"*, Paper AM-87-61, presented at the NPRA Annual Meeting, March 1987.

"UOP Process Solutions for Reformulated Gasoline", Copyright 1991, UOP/RFG SK 05-91, provided by UOP to ORNL.

TABLE TRI PENTANE/HEXANE (TOTAL RECYCLE) ISOMERIZATION

This is a total recycle isomerizer with molecular sieve which produces a high octane isomerate, approximately 4 RONC and 7 MONC greater than produced by unit PHI. The capital and operating costs are also higher.

Data sources include the following:

Sager, T.C. et al, *"Cost Effective Isomerization Options for Tomorrow's Light Gasoline Processing Options"*, Paper AM-89-12, presented at the NPRA Annual Meeting, March 1989.

Refinery Handbook, Hysomer and TIP System, Hydrocarbon Processing, September 1984, p.21.

TABLE H2P HYDROGEN PRODUCTION VIA STEAM REFORMING
TABLE H2X HYDROGEN PRODUCTION VIA PARTIAL OXYDATION

These process units produce hydrogen by steam reforming and partial oxidation, respectively. The steam reforming feeds include natural gas, propane, butane, and light naphtha. The partial oxidation plant feeds include low, intermediate, and high sulfur fuel oils.

Hydrogen is expressed in bblFOE throughout the model. Correspondence is 19,646 cf/bblFOE, equivalent to 50.9 bblFOE/MMcf of hydrogen. The hydrogen is produced at 97 percent purity, containing 3 percent methane.

Data sources are in-house EnSys data.

TABLE HLO HYDROGEN TRANSFER TO FUEL

This is essentially a model calibration table which permits the downgrading of produced hydrogen (95 percent purity) to fuel gas. The transfer ratio is established by matching the refinery hydrogen plant usage against known utilized capacity and reflects the fact that not all produced hydrogen, notably from catalytic reforming, is reclaimed for hydrotreating refinery streams.

TABLE SUL SULFUR PLANT

This unit reacts hydrogen sulfide with steam over iron oxide catalyst to produce sales grade sulfur. The unit is modeled after the Claus process with the capability to add a Stretford unit to reduce the hydrogen sulfide in the tail gas. The sulfur quantity is expressed in short tons and the coefficients in the unit are scaled by 0.1 to increase the LP solution efficiency.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys and in-house EnSys data.

TABLE FUM REFINERY FUEL PSEUDO-UNIT

Pseudo-unit for routing refinery streams to refinery fuel. This unit mixes refinery gases, naphthas, distillates and fuel oils to the model "FUL" row for internal refinery process unit fuel consumption. The feed coefficients reflect the bblFOE conversion factors.

The LP solution activities associated with this unit should be controlled and/or scrutinized since an over-constrained or otherwise infeasible model may be characterized by dumping high value streams to refinery fuel.

Data sources are not pertinent except for the bblFOE conversion factors. These are based on EnSys calculations and estimates.

TABLE STG STEAM GENERATION

TABLE KWG POWER GENERATION

Steam and power generation refinery utility units. These represent the generation of steam (in units of Mlb/day) from refinery fuel (in bblFOE) and electricity (in kilowatthours) from steam (Mlb/day). An efficiency of 31 percent is assumed for power generation and 70 percent for steam generation. The power and steam are consumed in the various refinery process units.

Data sources are the EIA RYM model data provided to ORNL and thereafter to EnSys, in-house EnSys data and EnSys calculations and estimates.

TABLE REL REFINERY LOSS PSEUDO-UNIT

This pseudo-unit is used to represent refinery light end losses and to adjust refinery loss to match calibration cases. The unit's single vector allocates light ends loss, as a fraction (currently 0.5 percent) of the crude run, across the light ends streams namely process gas, C_3's, C_4's, and light naphtha. The loss vector is equated with crude run via row FRL which is generated in ***Tables (R)POL***. Each crude processing vector in ***Table ACUCUTS*** has a 1 entry against FRL.

Estimates of the loss factors are based on in-house EnSys data and estimates based on calibration runs and knowledge of refinery losses.

TABLE PFA PRODUCED FUEL ADJUSTMENT PSEUDO-UNIT

This pseudo-unit is used to represent refinery propane and butane losses to refinery fuel gas (C_2 and lighter). The unit's single vector allocates C_3 and C_4 losses (transfers) to fuel gas as a fraction (currently 0.4 percent) of total crude run. The transfer vector is equated with crude run via row APF which is generated in ***Table (R)POL***. Each crude processing vector in ***Table ACUCUTS*** has a one entry against APF. Estimates of the fuel adjustment factors are based on in-house EnSys data and estimates based on calibration runs and knowledge of refinery losses.

TABLE ARD ATMOSPHERIC RESIDUUM DESULFURIZATION

This is an atmospheric residuum desulfurization process which uses residuum as feed to produce high-value light products, such as transportation fuels, low-sulfur fuel oil (0.1 percent - 0.5 percent sulfur), RFCC feed (3-6 MCR, 5-15 ppm vanadium & nickel), and coker feed. Chevron manufactures a hydrogen-efficient, fixed-bed atmospheric RDS hydroprocessing unit.

Source: • ORNL

TABLE CDT CATALYTIC DESULFURIZATION

Catalytic distillation from CDTech. This process uses two stages of catalytic distillation to desulfurize FCC gasoline (as high as 95 percent reduction), while producing high yield and very little octane loss. The first stage (a CDHydro® dehexanizer, combining fractionization with hydrogenation) receives FCC gasoline (C5+) to produce a C5/C6 overhead stream and a C7+ bottoms stream. The bottoms stream is further processed in the second stage (using CDHDS^{SM} technology, a catalytic distillation process combining hydrodesulfurization and distillation) to remove up to 95 percent of the sulfur. Octane number loss is limited to only 1.0 (R+M)/2. The output stream from the second stage is combined with the C5/C6 overhead stream from the first stage. Data sources are based on in-house Ensys data.

Source: • Rock, Kerry L., Richard Foley, and Hugh M. Putman, "Improvements in FCC Gasoline Desulfurization Via Catalytic Distillation," AM-98-37, presented at the 1998 NPRA Annual Meeting, March 15-17, 1998, San Francisco, California.

TABLE HCL LOW CONVERSION HYDROCRACKER

Added for additional processing flexibility to allow for low conversion hydrocracking. These units operate at pressure ranges of 800 to 1,200 psig, which is consistent with the typical design pressures for existing hydrotreating units. The diesel yield and quality are limited by constraints of existing equipment, and the primary objective is to improve the level of conversion and not product quality.

Source: • ORNL, in reference to "Hydrocarbon Processing," November 1999 Vol. 78 No. 11, "Use FCC feed pretreating methods to remove sulfur," by S. W. Shorey, D. A. Lomas, and W. H. Keesom, UOP LLC, Des Plaines, Illinois

TABLE SYG CATALYTIC NAPHTHA HYDROTREATER (not used)

Generic conventional cat naphtha desulfurization, producing 30-600 ppm sulfur cat naphtha product (depending on feed). A large drop in octane occurs. Data sources are based on in-house EnSys data.

Source: • EnSys technology database update, June 2002.

TABLE HS2 HYDRODESULFURIZER 2

A second-stage process to further desulfurizes the low sulfur output from the **HL1** process to produce a sub 10ppm sulfur distillate product stream. Limited commercial applications. Data sources are based on in-house EnSys data and report to EIA.

Source: • EnSys technology database update, June 2002.

TABLE HD1 DEEP HYDRODESULFURIZER 1

A first stage processing of *high*-sulfur straight run streams and medium plus *high*-sulfur *high*-conversion LCO streams to desulfurize and produce a 20-30 ppm output stream. This output is then processed in a second strage (**HD2**). Limited commercial applicatoins. Data sources are based on in-house EnSys data and report to EIA.

Source: • EnSys technology database update, June 2002.

TABLE HD2 DEEP HYDRODESULFURIZER 2

A second-stage process to takes coker gas and high-sulfur high-conversion LCO stocks (from **HD1**) to further desulfurize and produce a sub 10-ppm sulfur distillate product stream. Limited commercial applications. Data sources are based on in-house EnSys data and report to EIA.

Source: • EnSys technology database update, June 2002.

TABLE HCM HYDROCRACKER (PARTIAL)

This ExxonMobil process uses a hydrocracker to convert a variety of refinery feedstocks into high-quality, lighter products. The feedstock can include AGO, VGO, FCC light cycle oil, DAO, and Coker gas oil. The processing goal can be to maximize 1) conversion to naphtha for gasoline production, 2) production of specification jet fuel, and 3) production of middle distillates. Also, it can be used in partial conversion operations to produce highly upgraded, low-sulfur heavy gas oils. Single stage, once-through partial conversion, and two-stage processing designs are available. The single-stage, single-train reactor is designed to process in excess of 30,000 bpsd fresh feed capacity. The MAK process utilizes a dual catalyst system to react feedstock and hydrogen to achieve desulfurization, denitrogenation, demodulation, and hydrocracking. Optimal conditions are set depending on the processing goal. The product is gas oil with a 200-300 ppm sulfur content, with by-products produced at 50-100 ppm gasoline and 100-200 ppm sulfur distillate. Data sources are based on in-house EnSys data.

Sources: • EnSys technology database update, June 2002.

TABLE MOD CATALYTIC FLUIDIZED BED

A prospective commercial process by ExxonMobil to convert olefins to gasoline and distillate with 20 ppm sulfur content. ExxonMobil's Olefin to Gasoline (MOG) is a catalytic fluidized bed reactor process which utilizes a ExxonMobil proprietary shape-selective zeolite catalyst (ZSM-5) to convert light olefins (in lower value refinery streams) into high octane gasoline (C5+ components), or distillate (MOD process). The feed to the MOG reactor can include reactive olefins (ethylene and propylene in FCC offgas), propylene in FCC C3 LPG cut, butenes in MTBE raffinate, and pentenes, hexenes, and heptenes in light FCC gasoline. The feed is converted into C5+ through oligomerization, carbon number redistribution, hydrogen transfer, aromatization, alkylation, and isomerization reactions. The quality of MOG gasoline produced depends on the processing severity and the feed olefins, with yields ranging from 60 - 75 percent of high octane gasoline blendstock.

Typical qualities include: RONC (94 - 98), MONC (81 - 85), density (62 - 57 API), and RVP (7.2 psi/0.5 bar). The zeolite catalyst is considered to be environmentally safe, and can be reused in the FCC unit to increase octane quality.

Sources: • EnSys technology database update, June 2002.

TABLE MDH MOBIL HYDROGENATION (not used)

(renamed from MOH to MDH because PMM already had MOH defined for another unit)

An ancillary ExxonMobil process to saturate **MOD** distillate olefins. Produces a 20 ppm surfur distillate. Data sources are based on in-house EnSys data.

Source: • Ensys technology database update, June 2002.

TABLE OCT CATALYTIC FIXED-BED HYDROPROCESSOR

OCTGAIN is a commercially proven process from ExxonMobil which uses a proprietary catalyst system to selectively remove sulfur and saturate olefins from FCC naphtha or full range gasoline while maintaining (or even increasing) octane levels. Benzene content and vapor pressure in the product are nearly unchanged. The low mercaptan level of the desulfurized gasoline allows it to be directly blended into the refinery gasoline pool. There is a trade-off between C5+ yield and product octane (similar to naphtha reforming); however, the product yield has been increased with recent advancements in catalysts (OCT-220). The unit is a fixed-bed, low-pressure process that operates at essentially gasoline hydrofinishing conditions. Data sources are based on in-house EnSys data.

Source: • Shih, S.S., P.J. Owens, S. Palit, and D.A. Tryjankowski, "Mobil's OCTGAIN™ Process: FCC Gasoline Desulfurization Reaches a New Performance Level," AM-99-30, presented at the 1999 NPRA Annual Meeting, 1999.

• EnSys technology database update, June 2002.

TABLE SOX CAUSTIC SOX SCRUBBER

FCC regenerator gas caustic scrubber to meet current emission standards. Allows full benefit of FCC feed hydrodesulfurization. Many commercial applications. Data sources are based on in-house EnSys data.

Source: • EnSys technology database update, July 1999.

TABLE MTO METHANOL TO OLEFINS FLUID BED (not used)

An Exxon Mobil fluid bed process which converts methanol to olefins (MTO), and by-product gasoline with 5 ppm sulfur content (via subsequent oligomerization of the light olefin product). Provides olefins for ExxonMobil's MOG/MOD process. The MTO process was demonstrated in a semi-works plant (100 barrels per day) in Germany in 1982-83, a prospective commercial process.

(cogener)

TABLE CGN COGENERATION UNIT

This refinery process unit is used to produce steam and generate electricity for sale to the power grid. The fraction sold is contained in input ***Table SELCGN***, the electricity not sold is consumed by refinery process units. Data sources are from EIA-906 survey form.

(mchproc)

The processing units identified here are located outside the refinery at merchant facilities. These facilities provide the refinery with additional processing streams which are merged into the refining process. The following processing units located at the merchant facilities correspond with the refinery processing units defined as follows:

Merchant Processing Unit ID	*Refinery Processing Unit ID*
C4X	C4I
OLX	OLE
ETX	ETH
FUX	FUL
STX	STG
CGX	CGN

For detailed descriptions of these merchant processing units, refer to the corresponding refinery processing units defined above.

TABLE SMD SHELL MIDDLE DISTILLATE SYSTHESIS

A Shell GTL (gas to liquids) process for converting natural gas into ultra clean middle distillates, including diesel, kerosene, and naphtha. These GTL's can be used as a blending stock to improve the quality of other products. GTL products have no sulfur, aromatics, nitrogen compounds, or particulates.

Source: • EnSys technology database update, June 2002

TABLE SOD SASOL MIDDLE DISTILLATE UNIT

A Sasol Ltd. GTL (gas to liquids) process for converting natural gas into ultra clean middle distillates.

Source: • EnSys technology database update, June 2002

TABLE PSA PRISM PRESSURE SWING ABSORPTION- H_2 PRURIFICATION

Hydrogen recovery from refinery gas. Produces 95-99.999+% H_2 purity.

Source:
- EnSys technology database update, June 2002
- Hydrocarbon Processing, May 2002.

TABLE HPM H_2 PRURIFICATION

Hydrogen recovery from refinery gas using steam reforming.

Source:
- EnSys technology database update, June 2002
- Hydrocarbon Processing, May 2002.

TABLE HCU HYDROCRACKER(GASOIL)- ADVANCED TECHNOLOGY

Represents an advanced state-of-the-art hydrocracking technology designed to increase middle distillate yield by 5 to 15%, with middle distillate 10 ppm sulfur level products, 5-15% aromatics content, and at the 60 cetane level. Employs an efficient means of recycling unconverted oil to the cracking reactor, an enhanced hot separator, and back-staged reactors.

Source:
- EnSys technology database update, June 2002
- Hydrocarbon Processing, May 2002 (p. 117).

TABLE PSZ HYDRODESULFURIZATION (S ZORB) FOR DIESEL

Phillips' sulfur removing technology. It uses a regenerative sorbent to chemically attract and remove sulfur from gasolines, diesel, and distillates to 10 ppm levels. Operates at a very low net chemical hydrogen consumption, and at lower pressures than hydrotreating processes. It's capable of removing difficult sulfur species, such as 4,6 Dimethyldibenzothiophene.

Source:
- EnSys technology database update, June 2002
- Fuels Technology, www.fuelstechnology.com/szorbdiesel.htm

TABLE SUP SULPHCO SELECTIVE OXYDATION

Oxydation of sulfur containing components can effectively convert sulfur compounds. It is being investigated for practical use in refining. Oxidation can be very selective, and can be prformed at mild conditions.

Source:
- EnSys technology database update, June 2002
- Sulphco website, www.sulphco.com/technology.htm

TABLE CTX,CTZ COAL TO LIQUIDS

The coal-to-liquids process used in the PMM was developed based on the methodology described in a Mitretek Technical Report: "Coproduction: A Green Coal Technology," by David Gray and Glen Tomlinson, March 2001. The process consists of a coal gasification unit, followed by a Fischer-Troupe lification unit, with cogeneration. Specifically, the large-scale coproduction with no carbon sequestration (Figure 7 in the Report) is adopted as the generic facility for the CTL module. This CTL facility is capable of processing

16,400 TPD bituminous coal (e.g., Illinois Basin) with an energy content of 23 mmBtu/ton, and generating 33,200 BPD fuels and 696 MW net cogen for sale to the grid. The capacity factor (or utilization rate) is assumed to be 0.9.

Source:
- "Coproduction: A Green Coal Tehcnology," by David Gray and Glen Tomlinson