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EIA MODEL DOCUMENTATION:

PETROLEUM MARKET MODEL

OF THE

NATIONAL ENERGY MODELING SYSTEM

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Oil and Gas Analysis Branch

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Energy Information Administration

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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
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
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.
DOE	Department of Energy
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
EPA	Environmental Protection Agency
ETBE	Ethyl Tertiary Butyl Ether
IEA	International Energy Agency
IEO	EIA International Energy Outlook
LP	Linear Program
LPG	Liquefied Petroleum Gas
Mbbl/cd	Thousand Barrels Per Calendar Day
MMbbl/cd	Million Barrels Per Calendar Day
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
OSL	Optimization Subroutine Library
ORNL	Oak Ridge National Laboratory
PADD	Petroleum Administration for Defense District
PCF	Petrochemical Feed
PMM	Petroleum Market Module
RFG	Reformulated Gasoline
Rvp	Reid Vapor Pressure
RYM	Refinery Yield Model (EIA)
SCF	Standard Cubic Feet
SIC	Standard Industrial Classification
SPR	Strategic Petroleum Reserve
TAP	Toxic Air Pollutant
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).

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 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; 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 (PAD) District level.

1.3 Model Archival Citation

The PMM is archived as part of the National Energy Modeling System for AEO97. 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, Inventory of Input Data, Parameter Estimates, and Model Outputs; Appendix B, Detailed Mathematical Description of the 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, Biofuels Supply Submodule.

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 is 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, parameters for production functions which estimate the amount of domestic crude oil production, 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.

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

The PMM is comprised of five geographical regions, defined by the Petroleum Administration for Defense (PAD) Districts. Individual refineries are aggregated into one refinery representation for each PAD District. Product demands are input at the Census division level and end-use product prices are produced by Census division. A transportation structure linking the PAD District refining regions to the Census division demand regions is also represented. The PMM produces annual results, currently from 1990 through 2015.

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, distillate fuel, 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 traditional and reformulated gasoline, distillate fuel, low-sulfur diesel fuel, 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 and ethanol supply curves from the Biofuels Supply Submodule(Appendix I). 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.

- Parameters for production functions from the Oil and Gas Supply Model for estimating domestic production of crude oil. 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.

- Prices for natural gas and electricity from the Natural Gas Transmission and Distribution Model and the Electricity Market Model, 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-sulfur diesel and distillate fuel are provided to the PMM. The shares change over time, based on assumptions about market penetration (see Appendix F for more details). 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.

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.

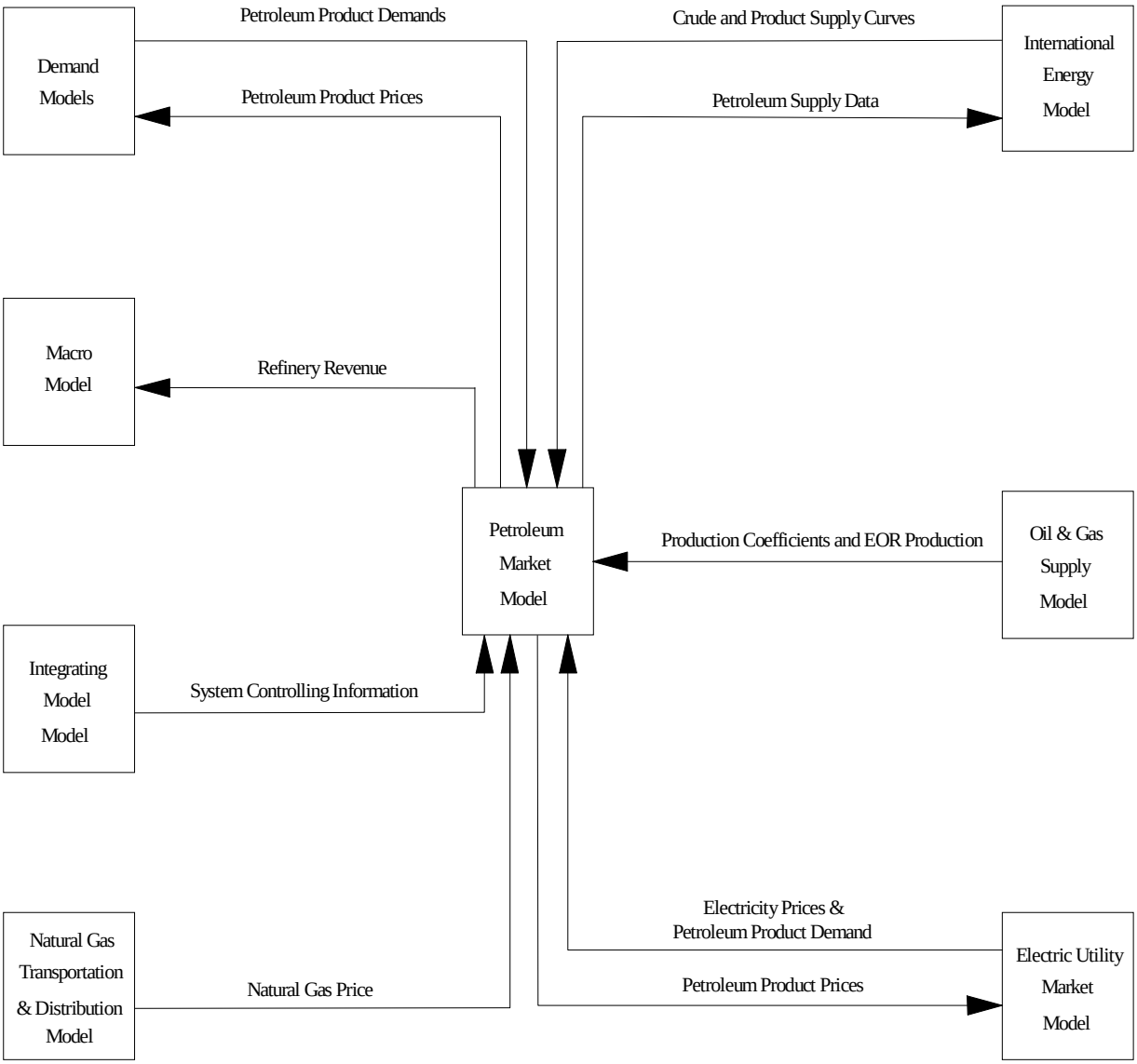
- Fuel consumption from refineries. This information is passed on to the Industrial Model for inclusion in the industrial sector totals. In addition, refinery cogeneration capacity and generation levels are also sent to the Industrial Model.

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

- The market prices and consumption of ethanol and methanol.

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 Philosophical or Theoretical Approach

The National Energy Modeling System, as a whole, produces a general equilibrium solution by iterating until convergence to a stable result occurs. 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 each of the five Petroleum Administration for Defense (PAD) Districts and represents an aggregation of the individual refineries in the PAD District. 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 five PAD District representation as a whole 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.

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 represents petroleum refining and marketing in the Intermediate Future Forecasting System, uses econometric equations to represent the relationship between refinery production costs (product costs) and product yields. The econometric equations are estimated from pseudodata derived from a refinery linear programming model. Pseudodata 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 pseudodata. An accounting/econometric framework is used to estimate sources of supply to meet demand. Product imports are 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 are not being reflected in the results since regional production levels are not represented.

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

- The current OMM cannot model changes in product specifications such as those included in the CAAA.

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

- The OMM cannot 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 pseudodata (involving several hundred runs), and (3) reestimate 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

[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).

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.

Each PAD District 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. 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 as well as costs resulting from the Clean Air Act Amendments of 1990 (CAAA90) and other environmental legislation.

The costs of producing new formulations of gasoline and diesel fuel that will be phased in as a result of the CAAA90 are determined within the linear programming (LP) representation by incorporating specifications and demands for these fuels. The PMM assumes that the specifications for these new fuels will remain the same as specified in current legislation.

Motor Gasoline Specifiations

The PMM models the production and distribution of four different types of gasoline: traditional, oxygenated, and reformulated. The following specifications are included in PMM to differentiate between traditional 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).

Starting in 1998 the specifications for traditional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of traditional 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 traditional 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 U.S. since January 1995. Beginning in 1998, the EPA will only certify reformulated gasoline using the "complex model," which allows refiners to specify reformulated gasoline based on emissions reductions either from their companies' 1990 baseline or from the EPA's 1990 baseline. 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." Specifications such as Rvp, aromatics, sulfur, and olefin content change in the year 2000 reflecting further emissions reductions required by CAAA90.

The CAAA90 provided for special treatment of California that would allow different specifications for oxygenated and reformulated gasoline in that State. In 1992, California requested a waiver from the winter oxygen requirements of 2.7 percent to reduce the requirement to a range of 1.8 to 2.2 percent. The PMM assumes that PAD District V refiners must meet the California specifications. The specifications for reformulated gasoline in PAD District V are the California standards.

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 Petroleum Administration for Defense (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 traditional, oxygenated, and reformulated gasolines by applying assumptions about the annual market shares for each type. The shares change over time based on assumptions about the market penetration of new fuels. Annual assumptions for each region account for the seasonal and city-by-city nature of the regulations. The market shares reflect the mandated use of reformulated blends in nonattainment areas as well as assumptions about opt-in and spillover demand from outside these areas. The PMM assumes a 5-percent spillover of oxygenated and reformulated gasoline into attainment areas.

The oxygenated gasoline shares throughout the forecast assume wintertime participation of 39 carbon monoxide nonattainment areas. Year-round consumption of oxygenated gasoline in Minnesota is assumed beginning in 1997 in accordance with State legislation. The PMM also assumes that, starting in 1995,

reformulated gasoline will be consumed in the nine required areas plus areas that had petitioned the EPA to opt in.[2] Areas that initially opted-in but opted-out as of June 1995 are not included.

Diesel Fuel Specifications and Market Shares

In order to account for diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Diesel fuel in Census divisions 1 through 9 is assumed to meet Federal specifications.

The PMM contains a sharing methodology to allocate distillate demands between low and high sulfur. Market shares for low-sulfur diesel and distillate fuel are estimated based on data from EIA's annual *Fuel Oil and Kerosene Sales Report 1992* (DOE/EIA-0535(92), October 1993). Since about 20 percent of current demand in the transportation sector is off highway, 80 percent of transportation demand for distillate fuel is assumed to be low sulfur. Consumption of low-sulfur distillate outside of the transportation sector is assumed to be zero.

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 reformulated fuels provisions of the CAAA90. Environmental costs associated with controlling pollution at refineries[3] 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.

State and Federal taxes are also added to transportation fuels to determine final end-use prices. Recent tax trend analysis indicated that State taxes increase at the rate of inflation, while Federal taxes do not. In the

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[2]Required areas: Baltimore, Chicago, Hartford, Houston, Los Angeles, Milwaukee, New York City, Philadelphia, and San Diego. Opt-in Areas Within: Texas, District of Columbia, New Jersey, Maryland, Delaware, New York, Connecticut, Virginia, New Hampshire, Massachusetts, Pennsylvania, Maine, and Rhode Island.

[3]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).

PMM, therefore, State taxes are held constant in real terms throughout the forecast while Federal taxes are deflated at the rate of inflation.

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 crudes 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

PMM refining regions are the five Petroleum Administration for Defense (PAD) districts. Individual refineries are aggregated into one linear programming representation for each PAD district region. In order to interact with other NEMS modules with different regional representations, certain PMM inputs and outputs are converted from a PAD district to a non-PAD district 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 by PAD district using historical data.

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 assume a 15-percent rate of return over a 15-year plant life. Expansion through 1998 is determined by adding to the existing capacities of units planned and under construction that are expected to begin operating during this time. Capacity expansion is done in 3-year increments. For example, after the model has reached a solution for forecast year 1999, the PMM looks ahead and determines the optimal capacities given the demands and prices existing in the 2002 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 2000, 25 percent in 2001, and 25 percent in 2002. At the end of 2002, the cycle begins anew.

Strategic Petroleum Reserve Fill Rate

The PMM assumes no additions for the Strategic Petroleum Reserve during the forecast period. Additions to the Strategic Petroleum Reserve have not been included in recent budgets.

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 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.

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.[4] Starting in 1995, gasoline sold in nine 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.

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.

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.[5] 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.

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

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

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.

3.5 Pseudodata/Econometric Equation Approach

The OMM, as described above, uses a pseudodata/econometric equation approach. The objective of this approach is 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 represents 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 are inaccuracy and preparation time. The model runs must be devised so that the pseudodata adequately cover the range of each of the inputs. Since the exact combination of inputs cannot usually be anticipated, the pseudodata 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 pseudodata, and the estimation of the equations all require substantial time and effort. The OMM equations were reestimated only about once every 4 years. However, because NEMS will be used for analytical studies as well as mid-range forecasting, the equations may have to be updated 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 pseudodata/econometric equation approach was not considered as a basis for PMM.

3.6 Linear Approximation Approach

Another type of pseudodata approach, called the linear approximation or lookup approach, was considered. Pseudodata 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 reestimated with each new set of pseudodata, 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 pseudodata 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 pseudodata/econometric equation approach.[6]

[6]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).

3.7 Abbreviated Linear Programming Approach

Extreme point modeling is similar to the pseudodata 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.[7]

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).

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[7]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 pseudodata 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 pseudodata 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,[8] although increasing the range and number of the modes can respond in part to this criticism.

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

3.8 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 pseudodata and extreme point approaches are not problems for a linear programming approach. The biggest drawbacks to LP models are size and execution time. The linear programming representation currently in the PMM will have to be reduced in size in order to achieve acceptable execution times.

4. Model Structure

During each NEMS iteration, product demand quantities and other variables supplied by NEMS models are used to update the PMM matrix. An optimal solution is obtained from the updated 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 matrix are both accomplished by executing FORTRAN callable LP subroutines available from an 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 matrix of the PMM. Appendix G documents the 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, and 4.4. 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 during any NEMS iteration.

- If the history switch is on and it is the first year and first iteration, historical values are read from an input file and the PMM LP matrix is loaded into memory to await processing in the PMM base 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

[1]Mathematical Programming System format.

performed because all historical data were retrieved and variables were updated on the first iteration of the first year.

- 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, and 4.3). Petroleum product prices and other PMM output data are retrieved from the LP optimal solutions and output variables are updated.

- 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 and 4.4). The capacity expansion methodology is described in more detail below.

- If it is a reporting iteration, the Short Term Energy Outlook (STEO) benchmarking switch is on, and it is NEMS year six; 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 MTBE 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 15-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 1996 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 forecast year 1997, capacity expansion is done in three year increments. For example, after the model has reached a solution for forecast year 1996, the PMM looks ahead and determines the optimal capacities given the estimated demands and prices expected in the 1999 forecast year. The PMM then allows 50 percent of that capacity to be built in forecast year 1997, 25 percent in 1998 and 25 percent in 1999. At the end of 1999, the cycle begins anew.

Figure 4.1 PMM Flow Diagram

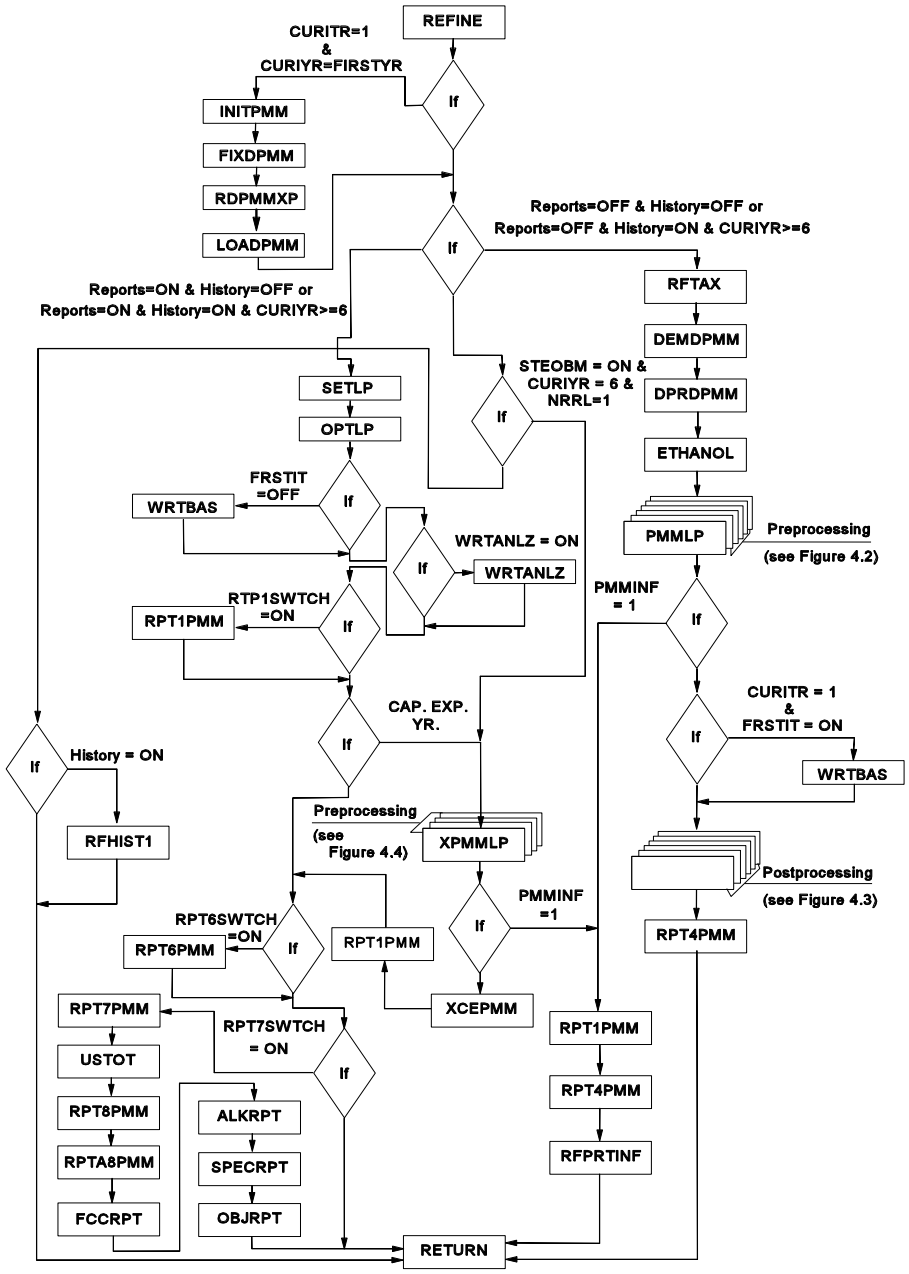


Figure 4.2 Matrix Preprocessing Subroutines

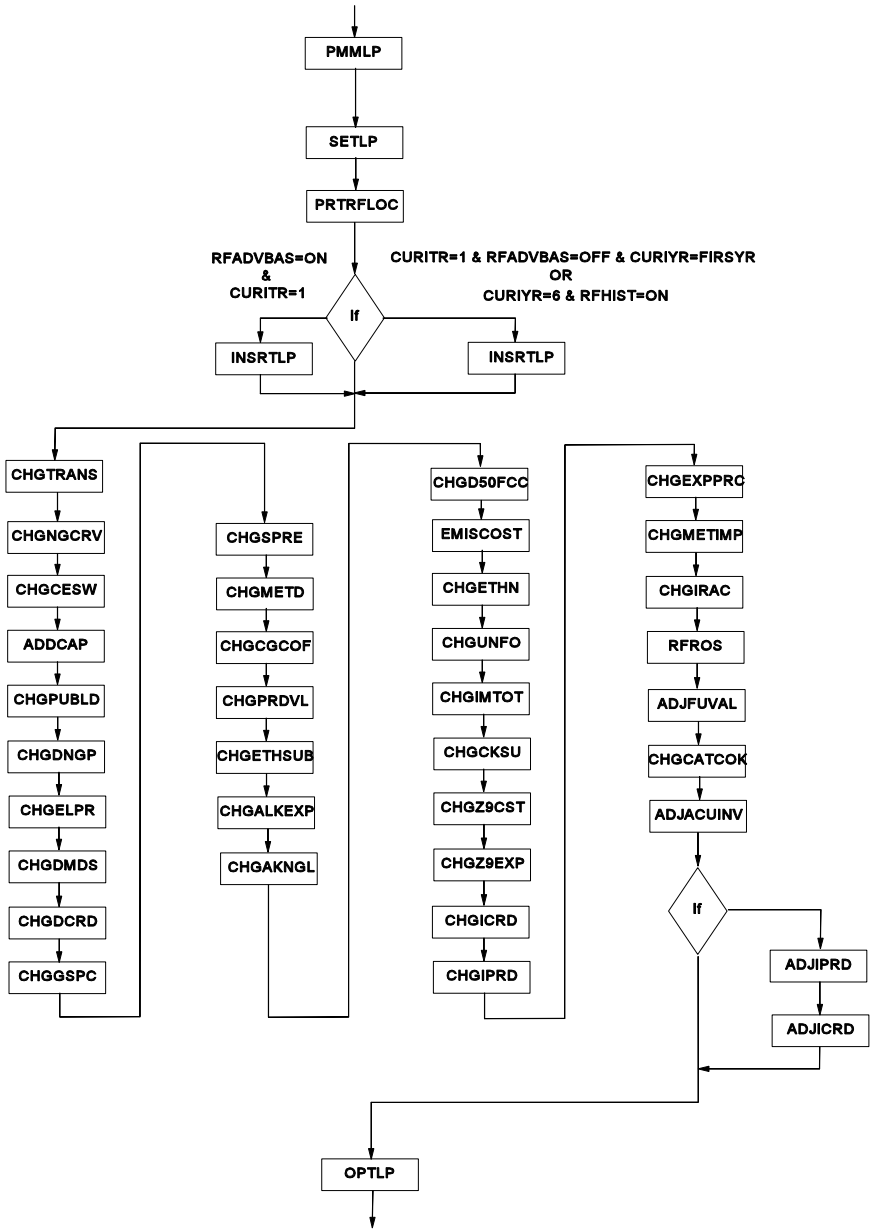


Figure 4.3 Matrix Postprocessing Suboutines

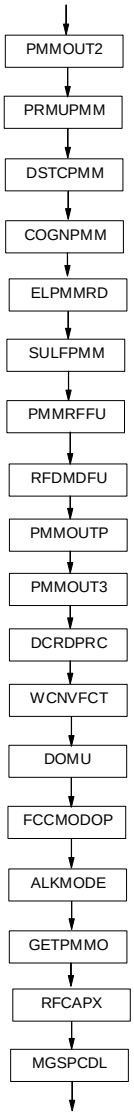
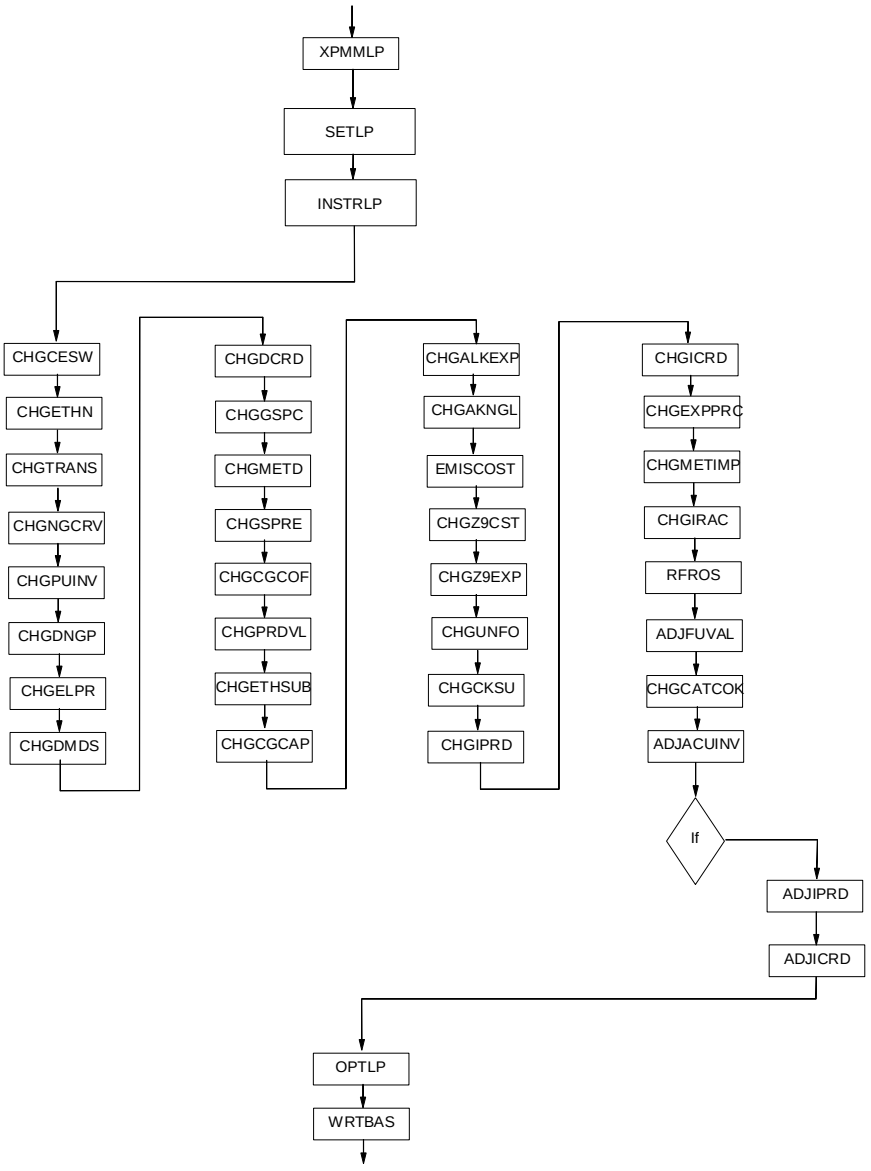


Figure 4.4 Capacity Expansion Subroutines



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:

$PUCUM_{pr,pu,yr} = 0.0$
$PUINV_{pr,pu,yr} = 0.0$
$RFQDINPOT_{pr,yr} = 0.0$
$PRDDMD_{pr,yr,prd} = 0.0$
$CRDOTHOT_{pr,yr} = 0.0$
$CRDUNACC_{pr,yr} = 0.0$
$CRDSTWDR_{pr,yr} = 0.0$
$CRDPRDSUP_{pr,yr} = 0.0$
$PRDSTKWDR_{pr,yr} = 0.0$
$BLDIMP_{pr,yr} = 0.0$
$QEXCRDIN_{pr,yr,pu} = 0.0$
$PUBASE_{pr,yr,pu} = 0.0$
$PUBASEUT_{pr,yr,pu} = 0.0$
$CFRGQ_{yr} = 0.0$
$CFTGQ_{yr} = 0.0$
$PETTR_{yr,7} = 11.67$ E85 price for STEO years 7 and 8
$PETTR_{yr,8} = 11.69$
$PMETR_{yr,7} = 9 .23$ M85 price for STEO years 7 and 8
$PMETR_{yr,8} = 9.23$

where:

pr = 1,2,3,4,5: PAD District
pu = 1,2,...40: Processing unit identifier index
yr = 1,2,...29: NEMS year index
prd = 1,2,...20: PMM product identifier index

(FIXDPMM) Read fixed inputs.

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

Equations: None.

Input Files:		
	MU1PRDS	Tax input data
	MU2PPRDS	Sectoral end-use markups
	QDCRDCF	Fixed Data input file

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

Purpose: The RDPMMXP subroutine read the SPRFLRT input file and updates PMM specific expectations 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 proecssing by the OML.

Purpose: This subroutine defines the OML model space for PMM. 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 and MPS format file and stores it in the model database.

Purpose: Converts a model from and MPS format file 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 database into memory and prepares it for optimization using the OML function WFLOAD.

Equations: None.

(RFHIST1) Read in history data for 1990 through 1994.

Purpose: RFHIST1 reads in history data from an external file and updates PMM output data for history years 1990 to 1995 and STEO year 1996 and 1997.

Equations: None.

Input File: ELCGPUR PMM historical data input file

(NEXTDATA) Advances file pointer one record.

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

Equations: None.

(RFTAX) Aggregates state and federal petroleum product taxes.

Purpose: RFTAX aggregates the states 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. Desegregates gasoline and distillate fuel into types. Calculates U.S. total petroleum product demand by sectors.

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

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

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

$$RFQMG_{cd}=(((QMGAS_{cd}+QMETR_{cd}*0.15+QMETR_{cd}*0.15)/CFMGQ/365)*1000$$

where;

RFQ(PR) = product demand by Census division
PRDDMD = product demand by Census division
Q(PR)AS = product demand in all sectors
Q(FPR)RF = product consumed for refinery fuel
CF(PR)Q = conversion factor from MMBtu/bbl
(PR) = product types
(FPR) = refinery fuel products identifier
cd = Census divisions 1 through 9
pd = PAD Districts 1 through 5
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:

$$PRDDMD_{cd,t} = RFQMG_{cd} * MGSHR_{cd,t}$$

where;

PRDDMD = product demand by Census division
t = motor gasoline product designator index, 2,3,4,5
MGSHR = motor gasoline market shares

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

Low-sulfur diesel fuel is determined as a share of transportation distillate demand (Refer to Appendix F, Estimation of Low-Sulfur Diesel Market Shares, for more details):

$$PRDDMD_{cd,14} = DSLSPLT*((QDSTR_{cd} /CFDSQ)/365)*1000$$

where;

14 = product index for low sulfur diesel (DSL)
DSLSPLT = 0.8
QDSTR = quantity of transportation 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 the transportation demand total, and 15 percent is added to gasoline demand. Finally, U.S. totals are calculated:

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

where;

11 = total U.S. demand index
pr = product index 1 through 19
cd = Census divisions 1 through 9
yr = NEMS year index 1 through 26

(DPRDPMM) Estimate domestic crude oil production.

Purpose: Estimates domestic crude oil production. More detail on the domestic crude production equations is available in the Oil and Gas Supply Model documentation.

Equations: Conventual domestic crude production are calculated for the nine lower 48 oil gas regions. Alaskan production and Enhanced Oil Recovery (EOR) production are obtained from the Oil Gas Supply Model (OGSM). Conventional lower 48 production is a function of wellhead price, beginning of year reserves, and the draw down rate such that:

$$RFQDCRD_{or,yr} = (OGPRRCO_{or,yr} *$$

$$((DCRWHP_{or,yr} / DCRCWHP_{or,yr-1})^{OGELSCO_{or,yr}}) *$$

$$OGRESCO_{or,yr})/365$$

and when the current iteration is the first iteration of a NEMS year

$$DCRDWHP_{or,yr} = OLALP_{or} * (WOP_{yr}-0.50)^{OLBTA_{or}}$$

and when the current iteration is past the first iteration of a NEMS year

$$DCRDWHP_{or,yr} = \text{Margin value of domestic crude from the } PMM_{(itr-1)}$$

where;

RFQDCRD = conventional domestic crude production, MMbbl/cd
DCRDWHP = domestic crude well-head price
OGPRRCO = production ratio, supplied by OGSM
OGELSCO = production elasticity, supplied by OGSM
OGRESCO = beginning of year reserves, supplied by OGSM
OLALP = regression constant, supplied by OGSM
WOP = World Oil Price, supplied by International
OLBTA = Wellhead to WOP price elasticity, from OGSM
0.5 = benchmark constant to adjust WOP, supplied by OGSM
or = Oil and gas region index, 1 through 9
yr = NEMS year index, 1 through 26
itr = NEMS iteration, 1 through 9
365 = Day per year

Total domestic production is then calculated by adding conventional production with the EOR production such that;

$$RFQTDCRD_{or,yr} = RFQDCRD_{or,yr} + ((OGQEORPR_{or,yr}/1000)/365)$$

where;

RFQTDCRD = Total domestic production, MMbbl/cd
OGQEORPR = EOR production, MBCY, supplied by OGSM
1000 = thousands to millions
365 = days per year
or = oil and gas regions, 1 through 6
yr = NEMS year index, 1 through 26

(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 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 SCOLP subroutine and calculates the processing unit build and investment bounds.

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

$$PUINV_{pd,yr+1,pu} = PUEXP_{pd,yr+3,pu} / 2$$
$$PUINV_{pd,yr+2,pu} = PUEXP_{pd,yr+3,pu} / 4$$
$$PUINV_{pd,yr+3,pu} = PUEXP_{pd,yr+3,pu} / 4$$

where;

PUINV = processing unit investment bound, Mbbl/cd
$PUEXP_{pd,yr+3,pu}$ = processing unit expansion as determined in expansion year yr
pu = processing unit index, 1 through 60
pd = PAD District index 1 through 5
yr = NEMS index years 7,10,13,16,19,22,25

The decision to allow half of the expansion to come on line in the first year of each three year period was made because of problems experienced in early testing of the model. This area of the model will be more thoroughly tested and the constraint may be changed. Capcity expansion for the crude unit

has been limited to 1.4 MBCD for each PADD in the low macroeconomic and high world oil price cases and 1.1 MBCD for each PADD for all other cases.

Processing unit cumulative builds, PUBLD is:

$PUBLD_{pd,yr,pu} = 0$; when yr = 7
$PUBLD_{pd,yr,pu} = PUBLD_{pd,yr-1,pu} + PUINV_{pd,yr-1,pu}$

where yr > NEMS index year 7
pu = processing unit index, 1 through 60
pd = PAD District index 1 through 5
yr = NEMS index years 7,10,13,16,19,22,25

(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

(RPT4PMM) Write report 4, PMM iteration reports.

Purpose: RPT4PMM pulls solution values from the LP using SROWLP, SCOLLP subroutines and writes to an external file PMM analyst reports during each NEMS iteration.

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

Output File: ALPHADN Iteration reports output file

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

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

Equations: None.

Output File: IMPCURV OMNI data table output file

(RPT7PMM) Write report 7, PMM forecast reports.

Purpose: RPT7PMM extracts 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

(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 crackers 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.

(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.

(PRTRFLOC) Prints the NEMS iteration and year to the OML output file.

Purpose: Prints the NEMS year and iteration in the OML output file, SYSPRINT, by forcing an OML error message using erroneous calls to the PMM LP matrix. This function facilitates the location of PMM information in SYSPRINT file for debugging purposes.

Equations: None.

(CHGTRANS) Updates the transportation costsof crude and product.

Purpose: Update the crude and product transportation cost with the U.S.

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

(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 fifty 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 eighty 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 point 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 points of the supply curve and the sum of activity levels on all points of the supply curve from the previous NEMS iteration solution. If the upper bound on the first point of the supply curve, just described falls below the lower bound on the first point of the curve, then the upper bound is set at value one percent above the lower bound on the first point of the curve.

(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. The upper investment bounds on the aromatics recovery processing unit (ARP) are set at 1000 MBCD during years seven and nine in PAD District five to alleviate the bottleneck on processing unit expansion inherent with the three year look-ahead methodology.

Equations: None.

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

Purpose: Sets the upper and lower bounds for the processing units investment colums to zero during initial model startup if the STEO benchmarking switch is off using the CBNDLP subroutine. During the first year 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.

(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 interruptable price of natural gas is used for the prices of gas to refineries in PAD Districts I and V. PAD District III refinery natural gas prices are calculated as the quantity weighted average natural gas well-head price in NGTDM regions two, four, and eight. Natural gas well-head prices in NGTDM regions three and five are used for PAD Districts II and IV respectively. These prices are converted to $/MCF. During the capacity expansion iteration the expected industrial interuptable 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 five PAD Districts 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 five PAD Districts.

Equations: Industry price of electricity is mapped from Census division to PAD District 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 all products except "other," the upper and lower bounds are equal. The bounds are set at the level of demand for each product in each Census division. For "other," the lower bound is zero and the upper bound is product demand in the Census division and year. This was done to provide more refining production flexibility and minimize infeasibilities. During the capacity expansion iteration the CHGDMDS updates bounds using the expected demands variables.

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: Conventional and Enhanced Oil Recovery (EOR) production are combined for the total 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: None.

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

Purpose: Sets the upper and lower bounds for SPR additions and crude oil exports. For both items, the upper and lower bounds are equal and are set using the CBNDLP subroutine. They are set as exogenous inputs to the program.

Equations: None.

(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 procssing unit.

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

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

where:
COEF = sales to grid coefficient
CNST = Percentage constant, 0.63237, 0.00870, 0.05092, 0.80775, 0.46287 for each PAD District I-V respectively.
PELAS = Prices of electricity to all sectors
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 objective row is updated as 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 blended into motor gasoline. Only the ethanol portion of E85 receives the ethanol subsidy

Equations: The ethanol subsidy declines in real terms from $18.29/Bbl by the the macroeconomic GDP deflator.

(CHGCGCAP) Updates the refinery cogeneration capacities.

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

Equations: No planned editions for AEO97 due to unavailable cogeneration data.

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

Purpose: The LP Alaskan export crude supply curve.

Equations: The prices steps on the supply curve are set as a function of world oil prices such that the price is the world oil price minus one dollars and thirty five cents. The volumes are set at fifty MBCD for each of the three points on the supply curve. These prices and volumes were set based on analyst judgement.

(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 mode in the fluid catalytic cracker.

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 through put. This value was made based on analyst judgement to meet the minimum winter mode of operation for the FCC unit.

(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 value determine by the Emission Policy Module.

(CHGETHN) Update ethanol supply curves in LP.

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.

Equations: Ethanol supply curve data are only available for Census divisions 3 and 4. In addition, the supply curves for Census divisions 3 and 4 have data for only the last four steps of the supply curve. The ethanol supply curve quantity units are converted to Mbbl/cd and the supply curve steps are converted from absolute quantities to differential step quantities. The ethanol supply curve volumes were adjusted to reflect nintey percent of current ethanol production on steps one and two and step three and four reflect eighty percent and one hundred sixty percent of current production.

(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:

$$ARB_{yr} = 0.90 * WOP_{yr}$$
$$NPP_{yr} = 1.14 * WOP_{yr}$$
$$HGM_{yr} = 1.02* WOP_{yr}$$

where

ARB = Atmospheric residual type B cost
NPP = Naphta parafinic cost
HGM = heavy gas oil medium sulfur cost
WOP = World oil price
yr = NEMS year, 1 through 26

(CHGEXPRD) Update total exported product.

Purpose: CHGEXPRD updates the total product export LP constraint by using the CRHSLP subroutine.

Equations: Total product exports are related to total petroleum product demand and inversely related to total imported petroleum products such that:

$$PRDEXP = (5.21E\text{-}08 / TOTPRDIMP^{1.51}) * ((TOTPRDDMD^{3.51}) * 1E06)$$

where,

PRDEXP = Total product exports
5.21E-08 = Log intercept
TOTPRDIMP = Total petroleum product imports
TOTPRDDMD = Total petroleum product demands
3.51 = Regression coefficient
1E06 = Unit conversion

(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 judgement 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. Distress export of petroleum coke cost is set at 10.0 percent of the high sulfur coke costs. A similar approach is used for sulfur, with a cost of $90/ton transformed into value of 5.0 times the WOP.

(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 time 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 ten 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 PAD District and five crude types to the PMM. These imported crude supply curves represent three price-quantity relationships for each imported crude in each PAD District. 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 PAD District adjustmensts the costs as follows: The imported crude prices were 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 orginial supply curves. These adjustments are estimated based on analyst judgement.

(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 PAD District. 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 make adjustments to the international supply curve prices and/or volumes.

Equations: Adjusts the prices on the imported product supply curves for the west coast PAD District five such that the addition amount is added to the import prices for each product:

Imported product	*Adjustment Amount*
RFG	1.62
N6B	3.03
DSL	1.95
N6I	3.03

In addition the volumes for the PAD District two, PAD District three, LPG were change such that each volume point on the supply curve are 33 and 25 MBCD respectively. Adjustments were made to the imported MTBE price such that the price is the WOP plus an adjusment factor for PAD District one through five. The adjustment factors are $13.97, $13.97, $13.00, $13.97, $16.89 for each PADD respectively.

These adjustments were made based on analysts judgement.

(CHGEXPPRC) Update exported petroleum product prices.

Purpose: This subroutine updates the objective row for each exported petroleum product.

Equations: None.

(CHGMETIMP) Updates the MTBE and methanol imports supply function.

Purpose: This subroutine updates the MTBE and 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 judgement.

(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 $0.50/bbl. This value was chosen based on analyst judgement.

(RFROS) Updates the renewable oxygenates constraint.

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

Equations: The motor gasoline minimum renewable oxygenates constraints are set at zero, fifteen, and thirty percent for the NEMS years 1994, 1995, 1996 and beyond respectively if the ROS switch is on. If the ROS switch is off the contraint is set to zero. For the AEO 1997 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 AEO 1997 this value was 1.07.

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 the current value as from the PMM database minus 0.0205.

(ADJACUINV) Updates the crude units investment costs

Purpose: This subroutine updates the 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.

4.3 Matrix Postprocessing Subroutines

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

(PMMOUT2) Update Common Block Variables

Purpose: Updates the PMM and NEMS system common block values of refinery production volumes by NEMSrefinery 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: Refinery fixed costs are added to the marginal prices of each product:

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

where:

P = refinery gate price of petroleum product pr

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. Fix cost are allocated only at 80, 80, 90, and 100 percent during the years 1995 to 1998 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

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

$P_{pr,cd}$ = 42 * (INTCP + SLP * (WOP/42) + (CNSNT * ((QRL + QRH)/QPRD)))
where:
P = refinery gate price of low and high sulfur residual fuel
INTCP = -0.57507 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
cd = Census division
42 = gallons per barrel

Demands for all four types of gasoline are summed by Census division:

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

where:
cd = Census division 1 through 9
t = motor gasoline index type 2,3,4,5

A national gasoline total is estimated by summing Census division totals:

$$MGDMD_{us} = \sum_{cd=1,9} MGDMD_{cd}$$

where:
us = U.S. total index 11
cd = Census division 1 through 9

National demand for each type of gasoline is estimated by:

$$MGDMD_{pr} = \sum_{cd=1,9} MGDMD_{pr,cd}$$

where:
pr = motor gasoline index 2,3,4,5
cd = Census division 1 through 9

A weighted average gasoline price is calculated for each Census division based on prices of the various types of gasoline:

$$PALMG_{cd} = \sum_{pr=2,3,4,5} ((PMGDMD_{pr,cd} * PRDDMD_{pr,cd})/MGDMD_{pr})$$

where:
pr = motor gasoline index 2,3,4,5
cd = Census division 1 through 9

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

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

where:
pr = petroleum product index 1 through 19
cd = Census division 1 through 9
t = total product demand index, 11, for product pr

A composite national average gasoline price is estimated by:

$$PALMG_{t} = \sum_{pr=2,3,4,5} (PMG_{pr} * MGDMD_{pr}/PRDDMD_{pr,t})$$

where:
PMGDMD = motor gasoline price
PRDDMD = product demand
MGDMD = motor gasoline demand
P = price of product
PMG = price of motor gasoline of type pr
pr = product index
cd = Census division
t = national total index

(DSTCPMM) Estimate distillation capacity and refinery utilization.

Purpose: Extracts capacity expansion information from LP. Estimates annual distillation capacity, utilization and annual and cumulative capacity expansion. Totals PAD District estimates to national estimates.

Equations: Refinery distillation capacity is taken at ninety percent total capacity to account for over optimization and in the LP. Units are converted to MMBCD and U.S. total are 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.

Electricity sales to grid are estimated in kWh:

$$RFCGGRIDPD_p = RFCGGENPD_p * PCGRDPD_p$$

Electricity used by refineries is estimated in kWh:

$$RFCGSELFPD_p = RFCGGENPD_p - RFCGGRIDPD_p$$

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 desegregates PAD District data to the Census divisions.

(SULFPMM) Estimate sulfur allowances.

Purpose: Estimates sulfur allowances awarded to small diesel refiners for years 1993 through 1999.

Equations: Calculate the possible allowance volumes from small refiners eligible for allowances in million barrels per year:

PAV =(QDSAS/CFDSQ) * 0.128 * 0.59

where:

QDSAS is the quantity of distillate produced
CFDSQ is distillate conversion factor MMBtu/bbl

The ratio factor 0.128 represents the proportion of distillate produced at small refineries and 0.59 represents the proportion of distillate that is diesel fuel.

Possible allowance volumes (PAV) are converted to possible allowance weight (PAW):

PAW = PAV * 302/2000

Requested allowances (REQALLOW) are estimated based on the weight of possible allowances:

REQALLOW = PAW * 0.00224 * 1000000 * 2

Refiner's sulfur allowances (RFSAL) are set equal to the minimum of the estimated amount (REQALLOW) or maximum allowable amount of 35,000.

RFSAL = MIN (REQALLOW,35000)

Allowances for 1993 are calculated as one-fourth of RFSAL due to the October 1993 start date.

(PMMRFFU) Estimate refinery fuel use.

Purpose: Estimates refinery consumption of distillate, residual fuel, coal, LPG's, natural gas, still gas, petroleum coke, and other petroleum products by PAD District.

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

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

Purpose: Converts PAD District level estimates for refinery consumption to Census division demands.

Equations: Calculates refinery fuel consumption in each Census division based on PAD District 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 at 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 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.

(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, exports, and motor gasoline.

Equations: The heat rate of imported petroleum product is calculated using the weighted average of each products heat rate. This calculation is also performed to the exported petroleum products. Each motor gasolines heat rate is used to calculated 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 LP solution.

Equations: None.

(ALKMODE) Retrieves the alkylation units mode of operation utilization.

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

Equations: None.

(GETPMMO) Retrieve objective functions value from the LP solution.

Purpose: This subroutine retrieve 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.

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.

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 OML specific 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 B

Mathematical Description of Model

APPENDIX B. Mathematical Description of Model

Each refiner is trying to minimize the cost of meeting demands. Therefore, the market moves toward lower-cost refiners who have access to crude oil and markets. A key premise is that the selection of crude oils, refinery process utilization, and logistics will adjust to minimize the overall cost of supplying the market with petroleum products.

In order to generate refined product prices, the PMM contains a static linear program model of the U.S. petroleum refining and marketing system that meets demand for refined products while minimizing costs. The PMM, like the other NEMS models, is written in FORTRAN. The RS6000 software includes the Optimization Modeling Library or OML, a set of FORTRAN callable subroutines. The LP portion of the PMM is a complete problem matrix prepared prior to NEMS processing. The LP remains in fast memory throughout the NEMS run, thereby avoiding many disk I/O operations.

It is necessary to view the PMM in the context of the NEMS program to understand its function. For each cycle, the main NEMS model calls the demand models to calculate energy demands. Each supply model is then called to calculate energy prices. When the prices and demands 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 the supply models, and the cycle is repeated. In the case of the PMM, a supply model, the refined product prices are obtained as the marginal prices from an optimal solution to the PMM LP. These product prices are output to the NEMS demand models. The LP matrix is updated with the new demands for refined products and the cycle continues until convergence is reached. The demand level modifications to the PMM LP and the re-optimization of the LP matrix, which remains in core memory, are accomplished by executing FORTRAN callable subroutines.

For AEO96 the original generation of the PMM matrix is performed using OML[1] and FORTRAN. OML (Optimization Modeling Library) is a library of FORTRAN callable subroutines for data table manipulation, matrix generation, and solution retrieval programs for report writing.. The matrix is solved with the optimizer, C-WHIZ[2].

B.1 Mathematical Formulation

The table of column activity definitions and row constraints defined in the PMM matrix incorporate certain premises which are described in Appendix A. The general structure of the matrix is shown in Table B1.

---

[1]Ketron Management Science, Inc., *Optimization Modeling Library, OML User Manual*, (November 1994).

[2]Ketron Management Science, Inc., *C-WHIZ Linear Programming Optimizer, User Manual*, (July 1994).

Table B1. PMM Linear Program Structure

PMM Linear Program Overview

	Crude Trans.	Purchases Crude Oil, Other Inputs	Crude Distillation	Other Process Unit Operations	Capacity Expansion	Stream Transfers	Blending	Product Sales	Product Trans.	Row Type	RHS
Objective	-ct	-c	-o	-o	-i			+p	-pt	NC	Max
Crude Oil Balance	+1 +1 -1	+1 +1 +1	-1 -1							GE	0
Intermediate Stream Balance			+y +y	-1 -1 +y +y		-1 +1 -1 +1	-1 -1			GE	0
Utilities		+1	-u	-u +1						GE	0
Policy Constraints				+z -z				+z -z		GE LE	0
Environmental Constraints			+q	+q						GE LE	E
Unit Capacities			+1	+1	-1					LE	K
Quality Specifications							+q +q -Q			GE LE	0
Product Sales							-1	-1	-1 +1 +1 -1	GE	0
Pipeline/Marine Capacities	+1 +1								+1 +1	LE	C
Bounds	Up/Lo/Fix	Up/Lo/Fix						Up/Lo/Fix			

Legend: c = crude cost; y = yield; u = utility consumption; K = unit capacity; o = operating cost; p = price; z = policy ratio; q = stream quality; ct = crude transportation cost; pt = product transportation cost; Q = product specifications; C = pipeline/marine capacity; E = environmental quality limit; i = investment cost

B.2 Matrix Indices

Several indices are used in the column and row definitions presented below. The definition of these indices are shown in Table B2.

Table B2. Index Definitions

Index Symbol	Description
(b)	Domestic crude oil production region
(c)	Crude oil type
(d)	Marketing region
(h)	Product recipe
(i)	Intermediate stream
(m)	Processing mode or shipping mode
(s)	Refinery stream
(p)	Refined product
(q)	Pricing level
(r)	Refinery region
(s)	Refinery stream
(u)	Processing unit type
(v)	Crude oil source
(y)	Product specification quality

B.3 Column Definitions

Table B3. Column Definitions

Column Notation	Description
$B_{a,d,q}$	Volume of alcohol (a) purchased in demand region (d) at price level (q). At present, this column exists only for ethanol.
$D_{p,d}$	Sales volume of product (p) in demand region (d).
$E_{u,r}$	Stream day capacity added during this simulated period for processing unit type (u) in refinery region (r).
$G_{i,p,r}$	Volume of intermediate stream (i) blended into spec blended product (p) at refinery region (r).
$H_{p,h,r}$	Volume of product (p) manufactured in refinery region (r) using recipe (h).
$H_{p,h,d}$	Volume of product (p) made by recipe (h) in demand region (d) by splash blending.
$I_{p,d}$	Volume of distress import of product (p) into demand region (d) where d = 2,3,7,8,9.
$I_{p,r,q}$	Volume of refined product (p) imported into refinery region (r) at price level (q).
$K_{u,r}$	Base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded.
$L_{u,r}$	Cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is fixed.
M_r	Volume of methanol consumed by the chemical industry in refinery region (r).
Mt	Total volume of U.S. methanol consumption by the chemical industry, an input.
$NZAMHN_q$	Volume at price discount q of Alaskan Crude (AMH) exports.
$NZAMHP_q$	Volume at price increment q of Alaskan Crude (AMH) exports.

Column Notation	Description
N_rNGRFN_q	Volume at price discount (q) of natural gas in refinery region (r).
N_rNGRFP_q	Volume at price increment (q) of natural gas in refinery region (r).
$O_{c,v,b}$	Export volume of crude oil (c) with source code (v) produced in domestic region (b). At present, only Alaska exports are allowed.
P_b	Volume of domestic crude oil produced at producing region (b).
$Pi_{c,r,q}$	Volume of imported crude oil type (c) imported by refinery region (r) at price level (q).
$Q_{p,r}$	Volume of spec product (p) manufactured in refinery region (r).
$Ra_{c,v,r}$	Crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).
$R_{u,r,m}$	Manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).
Tu	Total volume of imported unfinished oil over all refinery regions.
$T_{i,r}$	Volume of unfinished oil component (i) processed in refinery region (r).
TAAMHXZ	Volume of AMH crude transported from Alaska to Valdez.
$TCBN_r$	Total tax levied on total carbon emissions resulting from refinery operations in refinery region (r).
$Tx_{s,p,r}$	Volume of stream (s) transferred into product (p) in refinery region (r).
$Tx_{p,p',r}$	Volume of product (p) transferred into product (p') storage in refinery region (r).
$Tx_{s,s',r}$	Volume of stream (s) transferred to stream (s') at refinery region (r).
$U_{l,r}$	Quantity of utility (l) that is purchased in refinery region (r): (l) = KWH, STM, and NGF (power, steam, and natural gas fuel) with units in thousands of kWh, Mlbs., and MMcf respectively.
Vcj	Total dead weight ton capacity of Jones Act crude oil tankers. This column is constrained to some maximum.
V_{pc}	Total dead weight tons of Jones Act product tanker of shipping class (pc). This column is constrained to some maximum.
Vcts	Total crude oil transhipped from PAD District III to PAD District II. This column is constrained to some maximum.

Column Notation	Description
$Vcp_{b,r}$	Total crude oil shipped by pipeline from domestic producing region (b) to refinery region (r). This column is constrained to some maximum.
$Vpp_{r,d,m}$	Total volume of light products (p) shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.
$Vtpl_{r,d,m}$	Total volume of LPG products (p) shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.
$W_{a,d,r,m}$	Volume of alcohol (a) shipped from demand region (d) to refinery region (r) via mode (m).
$W_{p,r,d,m}$	Volume of product (p) shipped from refinery region (r) to demand region (d) via mode (m).
$W_{p,d,d',m}$	Volume of product (p) transhipped from demand region (d) to demand region (d') via mode (m).
$X_{p,d}$	Volume of product (p) exported from demand region (d).
$Y_{c,v,b,r,m}$	Volume of crude oil type (c) with source code (v) shipped from domestic region (b) to refinery region (r) via mode (m).
$Y_{c,v,r,r',m}$	Volume of domestic crude oil type (c) with source code (v) transhipped from refinery region (r) to refinery region (r') via mode (m).
Zt	Total volume of crude oil processed over all refinery regions.
ZET_d	Total volume of ethanol supplied from region (d).
ZOX_r	Total quantity of percent oxygen-barrels in reformulated gasoline produced in region (r).
ZZAMHTOT	Export volume of Alaskan Crude Oil.

B.4 Objective Function

The objective function has been established based on the premise that costs associated with product imports, non-crude oil inputs, and crude oil supplies are based on a given world oil price. With this in mind, the following objective function has been defined for PMM.

Given:

$PR_{p,d}$	is the unit price of product (p) sold in demand region (d). It is the price associated with the demand volume for that product in the specified demand region, i.e. it is associated with $D_{p,d}$. Similarly, each of the other 'PR' coefficients represents the unit price of the activity it is associated with.
PRAMH	is the target price for Alaskan crude exports.
$PRAMHN_q$	is the discount from Alaskan crude target price.
$PRAMHP_q$	is the premium added to the Alaskan crude target price.
PRAMHXZ	is the cost of transferring Alaskan exports to Valdez.
PR_rNGRFN_q	is the discount from target natural gas fuel price in refinery region (r).
PR_rNGRFP_q	is the premium added to the target natural gas fuel price in refinery region (r).
$C_{u,r,m}$	is the variable cost per unit of column $R_{u,r,m}$, i.e. the cost of one unit of manufacturing activity in mode (m) operation in processing unit (u) at refinery region (r). Similarly, each of the other 'C' coefficients represents the unit cost of the activity it is associated with in the objective function as stated below.
TE_d	is the sum of federal and state tax credits for use of ethanol in gasoline.

Maximize the difference between the following sum of product revenues and costs. Thus the objective function is represented as the maximization of a quantity defined by the following revenue terms:

$$\Sigma_d\Sigma_p\, D_{d,p}*PR_{d,p} + \Sigma_p\Sigma_h\Sigma_r\, H_{p,h,r}*PR_{p,h,r} + \Sigma_p\Sigma_h\Sigma_d H_{p,h,d}*PR_{p,h,d} + \Sigma_p\Sigma_d\, X_{p,d}*PR_{p,d}$$

$$+ \Sigma_d\, ZET_d * TE_d + ZZAMHTOT * PRAMH + \Sigma_q\, NZAMHP_q * PRAMHP_q$$

$$+ \Sigma_r\, \Sigma_q\, N_rNGRFN_q * PR_rNGRFN_q$$

minus the following cost terms:

$$\Sigma_a\Sigma_d\Sigma_q\ B_{a,d,q}{*}C_{a,d,q} + \Sigma_p\Sigma_r\ I_{p,r}{*}C_{p,r} + \Sigma_p\Sigma_d\ I_{p,d}{*}C_{p,d} + \Sigma_b\ P_b{*}C_b + \Sigma_c\Sigma_r\Sigma_q\ Pi_{c,r,q}{*}C_{c,r,q}$$

$$+ \Sigma_i\Sigma_r\ T_{i,r}{*}C_{i,r} + \Sigma_l\Sigma_r\ U_{l,r}{*}C_{l,r} + \Sigma_u\Sigma_r\Sigma_m\ R_{u,r,m}{*}C_{u,r,m} + \Sigma_u\Sigma_r\ E_{u,r}{*}C_{u,r} + \Sigma_u\Sigma_r\ L_{u,r}{*}C_{u,r} +$$

$$+ \Sigma_s\ \Sigma_i\ \Sigma_r\ \Sigma_l\ W_{a,d,r,m}{*}C_{a,d,r,m} + \Sigma_p\Sigma_r\Sigma_d\Sigma_m\ W_{p,r,d,m}{*}C_{p,r,d,m} + \Sigma_p\Sigma_d\Sigma_{d'}\Sigma_m\ W_{p,d,d',m}{*}C_{p,d,d',m}$$

$$+ \Sigma_c\Sigma_v\Sigma_b\Sigma_r\Sigma_m\ Y_{c,v,b,r,m}{*}C_{c,v,b,r,m} + \Sigma_c\Sigma_v\Sigma_r\Sigma_{r'}\Sigma_m\ Y_{c,v,r,r',m}{*}C_{c,v,r,r',m} + \Sigma_r\ TCBN_r$$

$$+ \Sigma_q\ NZAMHN_q * PRAMHN_q + TAAMHXZ * PRAMHXZ$$

$$+ \Sigma_r\Sigma_q\ N_rNGRFP_q * PR_rNGRFP_q$$

Note: $\Sigma_u\Sigma_r\Sigma_m\ R_{u,r,m}{*}C_{u,r,m}$ term is represented in the matrix as T(r)OVCOBJ + T(r)GPLOVC + T(r)MCHOVC.

B.5 Row Constraints

1. The implicit world oil price, WOP (the refiner's acquisition cost of imported crude oil), must be at least some fraction of premised WOP:

$$\Sigma_b P_b*C_b + \Sigma_c\Sigma_r\Sigma_q Pi_{c,r,q}*C_{c,r,q} - WOP * Nwop * Zt \geq 0$$

where:

P_b the volume of domestic crude oil produced in production region (b).

C_b the crude oil cost applicable to P_b. $/bbl

$Pi_{c,r,q}$ the volume of imported crude oil acquired by refinery region (r) of crude type (c) at price level (q). The volume of each crude type (c) is upper bounded by each step of the supply curve.

$C_{c,r,q}$ is crude oil cost applicable to $Pi_{c,r,q}$. $/bbl

WOP is the premised World Oil Price. $/bbl

Nwop is minimum fraction of the WOP by which refiners must acquire crude oils by volume weighted average; of course Nwop $\leq$ 1.

Zt is total processed crude oil over all refinery regions.

I.e., the average refiner acquisition cost of crude oil will be at least some input fraction of WOP.

Note: The index (v) denoting crude oil source is always "F" for imported crude. Therefore, no summation on (v) occurs for $Pi_{c,r,q}$.

2. The implicit world oil price, WOP (the refiner's acquisition cost of imported crude oil), must not be greater than some fraction of premised WOP:

$$\Sigma_b P_b*C_b + \Sigma_c\Sigma_r\Sigma_q Pi_{c,r,q}*C_{c,r,q} - WOP * Nwop * Zt \leq 0$$

where:

Xwop is the maximum fraction of the WOP by which refiners must acquire crude oils by volume weighted average, of course Xwop $\geq$ 1.

I.e., the average refinery acquisition cost of crude oil must not exceed some input fraction of WOP.

Note: This constraint in conjuction with the previous constraint confine the imported crude oil volumes so that their composite unit cost is close to the WOP. Since the costs of the 5 types of imported crude oil bracket the WOP, there is a continuum of import possibilities. Of course the crude oils vary in cost according to crude quality and transportation cost. However, to avoid infeasibilities due to an overly restrictive constraint, it is presently the practice to allow a variation of 50 cents per barrel. This is also made necessary when maximum import restrictions are placed on all but a "swing" crude oil. Clearly, if the tolerance is sufficiently relaxed, a single crude type could be imported rather than a reasonably balanced mix.

3. Calculate total crude oil processed by summing all crude oil volumes processed over all refinery regions:

$$\Sigma_c \Sigma_v \Sigma_r \, Ra_{c,v,r} - Zt = 0$$

where:

$Ra_{c,v,r}$ is the crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).
i.e. the total U.S. refined crude oil volume equals the sum of all crude oils refined over all regions.

4. Place an upper bound on product import volume:

$$\Sigma_p \Sigma_r \Sigma_q \, I_{p,r,q} \leq IPmax$$

where:

$I_{p,r,q}$ is the volume of product (p) imported into refinery region (r) at cost level (q).

Ipmax is the maximum assumed volume of imported products allowed into the U.S., an input value.

I.e., the sum of product volumes imported at all price levels over all refinery regions must not exceed some maximum.

5. Assure that the volumes of methanol consumed in each refinery region sum to the assumed total volume.

$$\Sigma_r \, M_r - Mt = 0$$

where:

M_r is methanol consumed by the chemical industry in refinery region (r).

Mt is total U.S. methanol consumption by the chemical industry, an input.

I.e., methanol consumed by the chemical industry in each refinery region must sum to the projected chemical industry total.

Note: The PMM models domestic methanol production aggregated to the refinery region level as though the plants were processing units integral to the refinery. The methanol production is allocated to two demands: chemical industry demand and transportation sector demand.

6. Limit capital investment for refinery expansion in each refinery region:

$$\Sigma_u E_{r,u} * A_{r,u} \leq Emax_r \quad \forall \quad r$$

where:

$E_{r,u}$ is a capacity addition for this operating year for processing unit type (u) in refinery region (r).

$A_{r,u}$ is the capital investment required per unit of capacity for processing unit type (u) in refinery region (r), million dollars per Mbbl/d.

$Emax_r$ is the upper limit on capital expenditures in refinery region (r), an input. $MM

I.e., total capital expenditures are limited for each refinery region. This limit allows the user to place limits on expansion for a given scenario. The default values are large such that they are not constraining, except in PADD I where a limit of $500 million dollars is the default. This value is based on analyst judgement to reflect the low expectation of refinery expansion on the East Coast.

Note: For NEMS production runs, this constraint has not been operative except for PAD District I. The assumption has been that environmental waivers and permits will preclude capacity additions in this region.

7. Limit total U.S. refinery capital investment:

$$\Sigma_r \Sigma_u E_{r,u} * A_{r,u} \leq Emax$$

where:

Emax is the upper limit on capital investment over all refinery regions, an input. $MM

I.e., total capital expenditures are constrained to some maximum. This limit allows the user to place limits on expansion for all regions in the United States. The default value is $50 billion and is not constraining.

Note: This constraint has been used to determine maximum product import needs by setting Emax to zero. It has not been operative in any production runs thus far. However, like the previous row, it is a potential policy exploration handle. For

instance, one could hypothesize that in a capital-short domestic environment, total industry investment is limited.

8. Limit the volume of unfinished oil processed in U.S. refineries:

$$\Sigma_c \Sigma_v \Sigma_r \, Ra_{c,v,r} - B1 * Tu \geq B0$$

where:

$Ra_{c,v,r}$ is the crude oil volume distilled in refinery region (r) from source (v) of crude oil type (c).

Tu is total processed unfinished oil over all refinery regions.

B0,B1 are regression equation coefficients (see Appendix A). B0 = 11,674.3, B1 = 4.087.

I.e., the maximum allowable unfinished oil processed is a linear function of total crude oil processed.

9. Limit the volume of each unfinished oil component processed in each refinery region:

$$A_{i,r} * Tu - T_{i,r} \geq 0 \quad \forall \; r, i$$

where:

$T_{i,r}$ is the volume of unfinished oil component (i) processed in refinery region (r).

$A_{i,r}$ is the fraction of component (i) of total unfinished oil that is processed in refinery region (r), an input.

I.e., the volume distribution of each type of unfinished oil processed at each refinery region is constrained to the historical pattern.

10. Balance by volume, at the demand regions, each alcohol purchased by the petroleum industry and domestic methanol shipped in from the refinery regions against alcohol blended by recipe in the demand region and alcohol shipped out of the demand region:

$$\Sigma_q \, B_{a,d,q} + \Sigma_r \Sigma_m \, W_{a,r,d,m} - \Sigma_p \Sigma_h \, H_{p,h,d} * A_{h,a} - \Sigma_r \Sigma_m \, W_{a,d,r,m} = 0 \quad \forall \; a, d$$

where:

$B_{a,d,q}$ is the volume of alcohol (a) purchased in demand region (d) at price level (q). At present, this column exists only for ethanol.

$W_{a,r,d,m}$ is the volume of alcohol (a) received in demand region (d) from refinery region (r) via shipping mode (m). This column exists only for methanol.

$H_{p,h,d}$ is the volume of recipe product (p) containing alcohol (a) consumed in demand region (d).

$A_{h,a}$ is the recipe fraction, by volume, of alcohol (a) in product (p), an input.

$W_{a,d,r,m}$ is the volume of alcohol (a) shipped from demand region (d) to refinery region (r) via mode (m). This column is valid only for ethanol. It is assumed that all ethanol purchases are made in the demand regions. Thus, ethanol needed by the refinery for processing or blending must be shipped from the demand regions.

I.e., in each demand region, all alcohol that is purchased or produced and shipped in from the refinery regions must be either splash blended into or shipped to a refining center.

11. For those products which are not blended by recipe at the demand regions, each demand region, and for each product, imports plus what is received via domestic shipment must equal the volume blended into recipes plus regular sales volume:

$$I_{p,d} + \Sigma_r\Sigma_m W_{p,r,d,m} - X_{p,d} - \Sigma_{p'}\Sigma_h H_{p',h,d}*A_{p,h} - D_{p,d} + \Sigma_q Dn_{p,d,q} - \Sigma_q Dp_{p,d,q} = 0 \quad \forall \; d, p$$

where:

$I_{p,d}$ is volume of product (p) imported into demand region (d).

$W_{p,r,d,m}$ is product (p) received in region (d) from refinery region (r) via mode (m).

$X_{p,d}$ is volume of product (p) exported from demand region (d).

$H_{p',h,d}$ is volume of product (p') manufactured by recipe (h) at demand region (d). This column exists only when product (p) is consumed to produce product (p) by a recipe blended at the demand region, i.e. splash blended at the terminals.

$A_{p,h}$ is the volume fraction of product (p) consumed by recipe (h), an input.

$D_{p,d}$ is a base sales volume of product (p) in demand region (d), this activity is fixed at the last NEMS iterative demand value; i.e., it does not impact the solution.

$Dn_{p,d,q}$ is an increment of sales volume decrease from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).

$Dp_{p,d,q}$ is an increment of sales volume increase from the base of $D_{d,p}$ for product (p) in demand region (d) at price level (q).

I.e., in each demand region, for each product, a balance is made whereby the volume imported and the volume shipped in from the refinery regions must equal the volume splash blended at the terminal plus straight sales volume.

Note: The columns $Dn_{p,d,q}$ and $Dp_{p,d,q}$ represent and allow incremental increases and decreases around the base demand value, $D_{p,d}$. An increase in volume around this

base is activated with an average input price determined by the demand elasticity of the product. The situation for incremental volume decreases is similar, except the price is given a negative value since the increment is essentially being backed out of the base volume. The purpose of this structure, as opposed to having a single fixed $D_{p,d}$, is to reduce wide swings in demand between NEMS iterations and thus make the marginal price more stable. This is called the "avoids" structure.

12. Balance, at each demand region, the volumes for each of the recipe products M85 and E85 - the products which are blended at the demand terminals - so that manufactured volume plus imports equals the recipe sales volume for these terminal splash blended recipes:

$$\Sigma_h H_{p',h,d} + I_{p',d} - D_{p',d} = 0 \quad \forall \quad p', d$$

where:

$p' \in p$ so that p' is a subset of all products and in fact, p' = E85 and M85.

$H_{p',h,d}$ is volume of product (p') made by recipe (h), produced at demand region (d) by splash blending.

$I_{p',d}$ is volume of product (p') imported into demand region (d).

$D_{p',d}$ is the sales volume of product (p') in demand region (d).

I.e., for each demand region, all M85 and E85 blended at the terminals plus M85 and E85 imported into the demand region must equal sales of the corresponding products.

13. For Census Divisions (demand regions) 5 and 6, balance the volume of each product that is shipped into the demand region with volume shipped out of the demand region:

$$\Sigma_m W_{p,r,d',m} + \Sigma_d \Sigma_m W_{p,d,d',m} - \Sigma_d \Sigma_m W_{p,d',d,m} = 0 \quad \forall \quad d', p$$

where:

$d' \in d$ and in fact, d' = Census Divisions 5 (South Atlantic) and 6 (South Central).

$W_{p,r,d',m}$ is volume of product (p) received by demand region (d') from refinery region (r) via pipeline (P/L) mode (m). These columns are generated only for the pipeline shipping mode when (d') is CD 6.

$W_{p,d,d',m}$ is volume of product (p) received in demand region (d') via transhipment from demand region (d) by mode (m), e.g. from 6 to 5 or from 5 to 2. For these columns, d' = d is not allowed.

$W_{p,d',d,m}$ is volume of product (p) transhipped from demand region (d') to demand region (d) by mode (m). However, for these columns, d' = d is allowed; in this case the activity represents P/L sales

I.e., pipeline product received in CD 5 or CD 6 must balance P/L product sales and transhipments.

Note: CD 5 and CD 2 (Mid Atlantic) receive much of their product volumes via pipeline (P/L) originating in PAD District III. Thus PAD District II production which is transported via P/L is split into one activity representing P/L product which is sold in CD 6 and another activity which is product transhipped through CD 6 into CD 5. Similarly, this latter component is split into two column activities, one which represents P/L product sales in CD 5, and another which represents product transhipped through CD 5 to CD 2.

14. Balance the domestic production of each crude type at each producing region against exports (Alaska only) and shipments to domestic refineries:

$$P_b * A_{c,v,b} - O_{c,v,b} - \Sigma_r \Sigma_m Y_{c,v,b,r,m} = 0 \quad \forall \; b, c, v$$

where:

P_b is total volume of domestic crude oil produced at producing region (b).

$A_{c,v,b}$ is the fraction by volume of P_b that is crude type (c) with source code (v), an input.

$O_{c,v,b}$ is the export volume of crude oil (c) with source code (v) produced in domestic region (b). At present, only Alaska crude exports are allowed.

$Y_{c,v,b,r,m}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m).

I.e, for each production region and crude oil type, domestic production must be balanced against exports and shipments to refinery regions.

15. Limit shipments of crude oil on Jones Act marine tankers:

$$\Sigma_c \Sigma_v \Sigma_b \Sigma_r \Sigma_{m'} Y_{c,v,b,r,m'} * A_c - Vcj = 0$$

where:

$m' \in m$ m' is the set of shipping modes that correspond to Jones Act crude oil tankers.

$Y_{c,v,b,r,m'}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m').

A_c is dead weight tons per barrel of crude oil of type (c), about 0.1344.

Vcj is total dead weight tons of Jones Act crude oil. This column is constrained to some maximum.

I.e., total Jones act crude oil shipments are limited by the existing fleet.

Note: This constraint is stated in the form 'X - MAX = 0' with bounds on MAX rather than in the form 'X $\leq$ MAX' (which is more straight forward from a mathematical standpoint) because this allows the analyst to add a minimum constraint or change over to a fixed constraint within the fortran code without a regeneration of the MPS file. Thus it is an artifice of convenience.

16. Limit shipments of refined product on Jones Act marine tankers by product class (clean, dirty...):

$$\Sigma_{p'}\Sigma_{r}\Sigma_{d}\Sigma_{m'} W_{p',r,d,m'}*A_{p'} - V_{pc} = 0 \quad \forall \text{ product class (pc)}$$

where:

$m' \in m$ m' is the set of shipping modes that correspond to Jones Act product tankers carrying product class (pc).

$p' \in p$ p' is the set of products which correspond to the product class (pc) of the particular constraint row.

$W_{p',r,d,m'}$ is volume of product (p') shipped from refinery region (r) to demand region (d) via mode (m').

A_c is dead weight tons per barrel of product (p), an input.

V_{pc} is total dead weight tons of Jones Act product of a shipping class (pc). This column is constrained to some maximum.

I.e., Jones Act product shipment volume is limited by tanker availability.

17. Allow and limit transhipments of crude oil from the Gulf Coast to the PAD District II refining region:

$$\Sigma_{v}\Sigma_{c} Y_{c,v,G,C,m} - Vcts = 0$$

where:

$Y_{c,v,G,C,m}$ is volume of crude oil type (c) with source code (v) that is transhipped from the PAD District III (code=G) refinery region to the PAD District II (code=C) refinery region.

Vcts is total crude oil transhipped from PAD District III to PAD District II. This column is constrained to some maximum

I.e., the volume of crude oil shipped from the Gulf Coast to PAD District II refineries is limited.

18. For each domestic crude oil producing region and refinery region (r) allowable combination, allow and limit pipeline shipments of crude oil:

$$\Sigma_c \Sigma_v \Sigma_m Y_{c,v,b,r,m} - Vcp_{b,r} = 0 \quad \forall \quad b, r$$

where:

$Y_{c,v,b,r,m}$ is volume of Crude oil type (c) that is shipped from domestic producing region (b) to refinery region (r) via pipeline mode (m).

$Vcp_{b,r}$ is total crude oil shipped by pipeline from domestic producing region (b) to refinery region (r). This column is constrained to some maximum.

I.e., limit the crude oil volume shipped by pipeline from each applicable producing region//refinery region pair.

19. For each refinery/demand region applicable combination, limit pipeline shipments of light products to available capacity:

$$\Sigma_{p'} \Sigma_r \Sigma_d \Sigma_m W_{p',r,d,m} - Vpp_{r,d,m} = 0 \quad \forall \quad r, d, m$$

where:

$p' \in p$ p' is the set of light products which can be shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$W_{p',r,d,m}$ is volume of product (p') shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$Vpp_{r,d,m}$ is total volume of light products (p') shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.

I.e., the volume of light products that can be shipped by pipeline from each refinery region to each demand region is limited by the available pipeline capacity.

20. For each refinery/demand region applicable combination, limit pipeline shipments of liquid petroleum gas volumes to available LPG pipeline capacity:

$$\Sigma_{p'} \Sigma_r \Sigma_d \Sigma_m W_{p',r,d,m} - Vtpl_{r,d,m} = 0 \quad \forall \quad r, d, m$$

where:

$p' \in p$ p' is the set of LPG products which can be shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$W_{p',r,d,m}$ is volume of LPG product (p') shipped from refinery region (r) to demand region (d) via pipeline mode (m).

$Vtpl_{r,d,m}$ is total volume of LPG products (p') shipped via pipeline mode (m) from refining region (r) to demand region (d). This column is constrained to some maximum.

I.e., the volume of LPG products that can be shipped by pipeline from each refinery region to each demand region is limited by the available pipeline capacity.

21. Refinery 'policy' table entries are adhered to:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{e,u,r,m} - A_{e,r} * Z_r FLO_u \quad \leq,\geq, = \; 0 \qquad \forall \quad e, r$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{e,u,r,m}$ is the coefficient entered into the processing unit (u) table for refinery region (r) in the operating mode (m) column at policy row (e), an input.

$A_{e,r}$ is the fractional amount of total capacity value entered in the policy table in row (e) for refinery region (r), an input, i.e., constraints may be introduced by the analyst via the "policy" rows.

Note: The type of row ($\leq,\geq,=$) is determined by the entry in column heading TYPE of the policy table (r)POL where $A_{e,r}$, appears. It may also be a non-constraining row, in which case the row is free. The total processing unit throughput is the base for the policy limits in each refinery region:

$$Z_r FLO_u - K_{u,r} - A_{u,r}*(L_{u,r} + E_{u,r}) \quad = \; 0 \qquad \forall \quad r, u$$

where:

$Z_r FLO_u$ is the sum of the base, build, and expanded capacity in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

22. For each applicable combination of domestic crude oil and refinery region, balance shipments received directly from the producing region plus transhipments received from other refinery regions against crude oil consumed at the refinery and crude that is transhipped to other refinery regions:

$$\Sigma_b \Sigma_m Y_{c,v,b,r,m} + \Sigma_{r'} \Sigma_m Y_{c,v,r',r,m} - \Sigma_{r'} \Sigma_m Y_{c,v,r,r',m} - Ra_{c,v,r} = 0 \quad \forall \; c, v, r$$

where:

$Y_{c,v,b,r,m}$ is volume of crude oil type (c) with source code (v) produced in domestic region (b) that is shipped to refinery region (r) via mode (m).

$Y_{c,v,r',r,m}$ is volume of domestic crude oil type (c) with source code (v) that is received at refinery region (r) by transhipment through refinery region (r') via mode (m).

$Y_{c,v,r,r',m}$ is volume of domestic crude oil type (c) with source code (v) that is transhipped through refinery region (r) to refinery region (r') via mode (m).

$Ra_{c,v,r}$ is volume of domestic crude oil type (c) with source code (v) that is processed through the atmospheric tower at refinery region (r).

I.e., for each domestic crude oil at each refinery region, the volume consumed at the refinery plus what is shipped out of the refinery region must equal what is shipped into the refinery region.

23. For each applicable combination of imported crude oil and refinery region, balance imports received directly plus imports transhipments received from other refinery regions against crude oil consumed at the refinery and crude that is transhipped to other refinery regions:

$$\Sigma_q Pi_{c,r,q} + \Sigma_{r'} \Sigma_m Y_{c,F,r',r,m} - \Sigma_{r'} \Sigma_m Y_{c,F,r,r',m} - Ra_{c,F,r} = 0 \quad \forall \; c, r$$

where:

$Pi_{c,r,q}$ is the quantity of imported crude oil acquired by refinery region (r) of crude type (c) at price level (q).

$Y_{c,F,r',r,m}$ is volume of imported crude oil type (c) that is received at refinery region (r) by transhipment from refinery region (r') via mode (m).

$Y_{c,F,r,r',m}$ is volume of imported crude oil type (c) that is transhipped from refinery region (r) to refinery region (r') via mode (m).

$Ra_{c,F,r}$ is volume of imported crude oil type (c) that is processed through the atmospheric tower at refinery region (r).

I.e., each imported crude oil must be balanced at each refinery by matching imports and what is received through transhipment against refinery consumption and what is transhipped to other refineries.

24. Balance each product at each refinery region:

$$Q_{p,r} + \Sigma_h H_{p,h,r} + \Sigma_q I_{p,r,q} + \Sigma_{p'} Tx_{s,p,r} - \Sigma_{p'} Tx_{p,p',r} - \Sigma_{p'}\Sigma_h H_{p',h,r} * A_{p,h}$$

$$- \Sigma_m \Sigma_d W_{p,r,d,m} = 0 \quad \forall \quad p, r$$

where:

$Q_{p,r}$ is volume of spec product (p) manufactured in refinery region (r). When product (p) is a spec product, column $H_{p,h,r}$ does not exist.

$H_{p,h,r}$ is volume of product (p) manufactured in refinery region (r) using recipe (h). When this column is active for product (p), column $Q_{p,r}$ does not exist.

$I_{p,r,q}$ is volume of refined product (p) imported into refinery region (r) at price level (q).

$Tx_{s,p,r}$ is the volume of stream (s) transferred into product (p) in refinery region (r).

$Tx_{p,p',r}$ is the volume of product (p) transferred into product (p') storage in refinery region (r).

$H_{p',h,r}$ is the volume of product made by recipe (h) at refinery region (r) in which product (p') is an ingredient.

$A_{p,h}$ is the volume of product (p) consumed per unit of recipe (h), an input.

$W_{p,r,d,m}$ is the volume of product (p) shipped from refinery region (r) to demand region (d) via mode (m).

I.e., for each product at each refinery, the volume manufactured plus volume imported plus volume transferred from another higher quality product must equal to the volume transferred to other lower quality products plus the amount consumed by recipe plus the volume shipped to market.

25. Balance each utility at each refinery region:

$$U_{l,r} + \Sigma_u \Sigma_m R_{u,r,m} * A_{l,u,r,m} - \Sigma_p Q_{p,r} * A_{l,p,r} - \Sigma_p \Sigma_h H_{p,h,r} * A_{l,h,r} = 0 \quad \forall \quad r, l$$

where:

$U_{l,r}$ is the quantity of utility (l) that is purchased in refinery region (r). Of course (l) = KWH, STM, and NGF (power, steam, and natural gas fuel) with units in thousands of kWh, lbs., and Mcf respectively.

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{l,u,r,m}$ is the quantity of utility (l) consumed (-) or manufactured (+) per unit of operation of processing unit (u) in mode (m) in refinery region (r). The (u) index includes the utility manufacturing units.

$Q_{p,r}$ is the volume of spec product (p) manufactured at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,p,r}$ is the quantity of utility (l) consumed per unit of spec product (p) manufactured at refinery region (r).

$H_{p,h,r}$ is the volume of product (p) manufactured by recipe blend (h) at refinery region (r). This column exists only when product (p) is a spec blend.

$A_{l,h,r}$ is the quantity of utility (l) consumed per unit of recipe product (h) manufactured at refinery region (r).

I.e., for each utility at each refinery region, the quantity purchased plus the amount manufactured must equal the consumption.

26. Constrain each processing unit throughput to maximum capacity at each refinery region:

$$\Sigma_m R_{u,r,m} - K_{u,r} - A_{u,r}*(L_{u,r} + E_{u,r}) = 0 \quad \forall \quad r, u$$

where:

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$K_{u,r}$ is the base processing capacity in processing unit (u) at refinery region (r) in Mbbl/cd. This column is upper bounded rather than fixed. See note below.

$A_{u,r}$ is the stream factor for processing unit (u) at refinery region (r) defined as the ratio of calendar day capacity to stream day capacity.

$L_{u,r}$ is the cumulative stream day capacity added for processing unit (u) at refinery region (r) during the previous simulated periods. This column is, of course, fixed.

$E_{u,r}$ is the stream day capacity added during this simulated period for processing unit (u) at refinery region (r). This column is generally upper bounded.

I.e., the activity of a particular processing unit must be limited to the maximum operating capacity.

Note: By making this row fixed with the base capacity upper bounded, the processing throughput is calculated as $K_{u,r} + A_{u,r}*(L_{u,r} + E_{u,r})$. Of course, in a model lacking capacity expansion capability, the capacity constraint row is commonly constructed as throughput and is equal to or less than a right-hand-side capacity value so that the throughput is merely the row activity.

27. Balance each intermediate refinery stream at each refinery region:

$$\Sigma_u \Sigma_m R_{u,r,m} * A_{i,u,r,m} + \Sigma_s (Tx_{s,i,r} - Tx_{i,s,r}) - \Sigma_p G_{i,p,r} - \Sigma_p \Sigma_h H_{p,h,r} * A_{i,h} = 0 \quad \forall \; i, r$$

where:

$i \in s$ i.e., the intermediate streams are a subset of all refinery streams.

$R_{u,r,m}$ is the manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r).

$A_{i,u,r,m}$ is the volume fraction of intermediate stream (i) created (or consumed if the sign is negative) per unit of manufacturing activity level in mode (m) operation in processing unit (u) at refinery region (r) for processing unit (u) at refinery region (r).

$Tx_{s,i,r}$ is the volume of stream (s) transferred to intermediate stream (i) at refinery region (r).

$Tx_{i,s,r}$ is the volume of intermediate stream (i) transferred to stream (s) at refinery region (r).

$G_{i,p,r}$ is the volume of intermediate stream (i) blended into spec blended product (p) at refinery region (r).

$H_{p,h,r}$ is the volume of product (p) manufactured according to recipe (h) at refinery region (r).

$A_{i,h}$ is the volume fraction of intermediate stream (i) consumed per unit volume of product manufactured according to recipe (h) at refinery region (r).

I.e., at each refinery region, each intermediate stream must be volume balanced so that the amount manufactured plus the amount transferred from higher quality streams must equal the volumes consumed by manufacturing processes, the amount that may be transferred to other lower quality streams plus the volumes blended into spec and recipe products.

28. Constrain qualities of spec blended products:

$$\Sigma_i G_{i,p,r} * A_{y,i,p} - Q_{i,r} * A_{y,p,r} \quad \leq, \geq, = \quad 0 \quad \forall \; y, p, r$$

where:

$G_{i,p,r}$ is the volume of intermediate stream (i) blended into spec-blended product (p) at refinery region (r).

$A_{y,i,p}$ is the blend value of property (y) for spec product (p) of stream (i).

$Q_{p,r}$ is the total volume of spec-blended product (p) manufactured at refinery region (r).

$A_{y,p,r}$ is the constraining value of property (y) that spec product (p) must adhere to; e.g., an octane number, at refinery region (r).

Note: The row type varies depending upon whether the blend specification quality is a maximum, minimum, or fixed value.

i.e., for each spec for each product at each refinery region, the aggregate spec value of the product determined by volume weighting the spec properties of the consumed blending stocks must not violate the specification limit.

29. Sum oxygen percentage contribution by oxygenates blended to reformulated gasoline

$$\Sigma_{OX}\, G_{OX,RFG,r} * PO_{OX} + H_{ETH,RFG,r} * PO_{ETH} * F_{ETHRFG} + H_{ETH,RFH,r} * PO_{ETH} * F_{ETHRFH} = ZOX_r$$

where:

$G_{OX,RFG,r}$ is the volume of oxygenate stream (OX) blended to RFG in region (r).
PO_{OX} is the percentage oxygen in oxygenate stream (OX). This group includes MTBE, TAM, and THM from methanol and ETB, TAE, and THE from ethanol. Also included is the ethanol splash blended.
$H_{ETH,RFG,r}$ is the volume of RFG splash blended with ethanol in region r.
PO_{ETH} is the percentage oxygen in ethanol
F_{ETHRFG} is the fraction of ethanol in RFG for 2.0% min oxygen (= 5.8%).
$H_{ETH,RFH,r}$ is the volume of RFH splash blended with ethanol in region r.
F_{ETHRFH} is the fraction of ethanol in RFH for 2.7% min oxygen (= 7.8%).
ZOX_r is the total volume in units of percent oxygen-barrels of RFG.

30. Sum oxygen percentage contribution by renewable oxygenates blended to RFG.

$$\Sigma_{OE}\, G_{OE,RFG,r} * PO_{OE} + H_{ETH,RFG,r} * PO_{ETH} * F_{ETHRFG} + H_{ETH,RFH,r} * PO_{ETH} * F_{ETHRFH} \geq L * ZOX_r$$

where, in addition to the terms defined in equation 29:

$G_{OE,RFG,r}$ is the volume of renewable oxygenate stream (OE) blended to RFG in region (r).
PO_{OE} is the percentage oxygen in oxygenate stream (OE). This group includes ETB, TAE, and THE from ethanol. Also included is the ethanol splash blended.
L is the volume fraction of the oxygen that must come from renewable oxygenates, i.e., ethanol, ethylbenzene (ETB) and ethyl ethers (TAE and THE).

31. Calculate refinery consumption of natural gas supply by summing volumes processed for each refinery region:

$$\Sigma_q N_r NGRFN_q + \Sigma_q N_r NGRFP_q - U_r NGF = 0$$

where:

$N_r NGRFN/P_q$ is the volume of natural gas consumed in refinery region (r) at supply price delta (q).
$U_r NGF$ is the total volume of natural gas consumed in refinery region r.

32. Place an upper bound on each natural gas supply step volume:

$N_r NGRFN/P_q \leq NG_q$ max

where:

$N_r NGRFN/P_q$ is the volume of natural gas allowed on step q in region (r) at cost a cost delta.

NG_q max is the maximum volume of natural gas supply allowed, based on an input value. Note that step N1 has a minimum lower bound volume.

33. Calculate Alaskan crude export volumes:

$\Sigma_q NZAMHP_q + \Sigma_q NZAMHN_q - ZZAMHTOT = 0$

where:

$\Sigma_q NZAMHP_q$ Volume at price increment q of Alaskan Crude (AMH) exports.
$\Sigma_q NZAMHN_q$ Volume at price discount q of Alaskan Crude (AMH) exports.

34. Place an upper bound on each Alaskan crude supply step volume:

$NZAMHx_q \leq NZAMHx_q$ max

where:

$NZAMHx_q$ Volume at price increment/discount q of Alaskan Crude (AMH) exports.

$NZAMHx_q$ max is the maximum volume of crude export allowed, based on an input value.

35. In addition to the above, several non-constraining rows exist merely as a convenience to sum over certain columns via the row activity parameter.

B.6 Row and Column Cross References

The PMM LP matrix is generated from a program written in the FORTRAN language using callable subroutines from OML. The correspondence between the rows and the column symbols in the preceding matrix description and the generated matrix names of PMM are shown in Table B4.

Table B4. Column Cross References

Column Notation	Matrix Name
$B_{a,d,q}$	C(d)(a)R(q)
$D_{p,d}$	D(d)(p)S1 & D(d)(p)SX
$E_{u,r}$	E(r)(u)INV
$G_{i,p,r}$	B(r)(p)(i) & F(r)(p(i)
$H_{p,h,r}$	X(r)(h)(p) & G(r)(i)(p)
$H_{p,h,d}$	X(d)(h)(p)
$I_{p,d}$	I(d)(p)Z9
$I_{p,r,q}$	I(r)(p)R(q)
$K_{u,r}$	K(r)(u)CAP
$L_{u,r}$	L(r)(u)BLD
M_r	G(r)METDEM
Mt	D@METS1
N_rNGRFN_q	N(r)NGRFN(q)
N_rNGRFP_q	N(r)NGRFP(q)
$NZAMHN_q$	NZAMHN(q)
$NZAMHP_q$	NZAMHP(q)
$O_{c,v,b}$	O@CRDEXP
P_b	P(b)DCRQ1
$Pi_{c,r,q}$	P(r)F(c)Q(q)

Column Notation	Matrix Name
$Q_{p,r}$	Q(r)(p)
$Ra_{c,v,r}$	R(r)ACU(v)(c)
$R_{u,r,m}$	R(r)(u)(m) & H(r)(u)(m)
Tu	T@UNFTOT
$T_{i,r}$	T(r)UNF(i)
TAAMHXZ	TAAMNXZ
$TCBN_r$	T(r)CBNTAX
$Tx_{s,p,r}$	T(r)(s)(p)
$Tx_{p,p',r}$	T(r)(p)(p')
$Tx_{s,s',r}$	T(r)(s)(s')
$U_{l,r}$	U(r)(l)
U_rNGF	U(r)NGF
Vcj	VTVC(m)CP
V_{pc}	VTVP(m)CP
Vcts	VTPCGAC
$Vcp_{b,r}$	VTPC(b)(m)(r)
$Vpp_{r,d,m}$	VTPP(r)(d)(m)
$Vtpl_{r,d,m}$	VTPL(r)(m)(d)
$W_{a,r,d,m}$	W(r)(a)(m)(d)
$W_{a,d,r,m}$	W(d)(a)(m)(r)
$W_{p,r,d,m}$	W(r)(p)(m)(d)
$W_{p,d,d',m}$	W(d)(p)(m)(d')
$X_{p,d}$	D(d)(p)Z9
$Y_{c,v,b,r,m}$	Y(b)(v)(c)(m)(r)

Column Notation	Matrix Name
$Y_{c,v,r,r',m}$	Y(r)(v)(c)(m)(r')
Zt	Z@TOTCRD
ZET_{d}	Z(d)ETHTAX
$Z_{r}FLO_{u}$	Z(r)FLO(u)
ZOX_{r}	Z(r)RFGOXY
ZZAMHTOT	ZZAMHTOT

Table B5. Row Cross References

Row Number	Matrix Name
1	Z@IRACN
2	Z@IRACX
3	Z@CRDTOT
4	A@PRDIMP
5	D@MET
6	A@INVST
7	A(r)INVST
8	F@TOTCRD
9	F(r)UNF(i)
10	D(d)(a)
11	D(d)(p)
12	D(d)(p')
13	M(d)(p)
14	C(b)(v)
15	TVC(m)CP
16	TVP(m)CP
17	TPCGAC
18	TPC(b)(m)(r)
19	TPP(r)(m)(d)
20	TPL(r)(m)(d)
21	P(r)(e), Z(r)CAP(u), H(r)(e), G(r)(e)
22	C(r)(v)(c)
23	C(r)F(c)
24	M(r)(p)
25	U(r)(l)
26	L(r)(u)CAP, H(r)FUMCAP
27	B(r)(i), G(r)(i), H(r)(i)
28	Q(r)(p)(y)
29	S(r)RFGOXY
30	Q(r)RFGREN
31	Z(r)NGFSUM
32*	N(r)NGRFN/P(q)
33	ZZAMHSUM
34*	NZAMHN/P(q)

* Bound on column variable.

APPENDIX C

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APPENDIX C Bibliography

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47. Also see citations in Appendix A.

APPENDIX D

Model Abstract

APPENDIX D Model Abstract

D.1 Model Name:

Petroleum Market Model

D.2 Model Acronym:

PMM

D.3 Description:

The Petroleum Market Model is a simulation of the U.S. petroleum industry. It includes 12 domestic crude oil production regions, 5 refining centers with full processing representations and capacity expansion capability and gas plant liquid production, and 9 marketing regions. The heart of the model is a linear program optimization which ensures a rational economic simulation of decisions of petroleum sourcing, resource allocations, and the calculation of marginal price basis for the products. Eighteen refined products are manufactured, imported, and marketed. Seven of these products are specification blended, while the remaining 11 are recipe blended. Capacitated transportation systems are included to represent existing intra-U.S. crude oil and product shipments (LPG, clean, dirty) via pipeline, marine tanker, barge, and truck/rail tankers. The export and import of crude oil and refined products is also simulated. All imports are purchased in accordance with import supply curves. Domestic manufacture of methanol is represented as though the processing plants were a part of the refinery complexes whereas ethanol sources are treated as merchant. Transportation is allowed for ethanol shipments to the demand region terminals for splash blending.

The program is written in FORTRAN which includes callable subroutines allowing full communication with the LP portion of the model which is in the form of an MPS resident file.

D.4 Purpose of the Model:

The PMM models domestic petroleum refining activities, the marketing of petroleum products to consumption regions, the production of natural gas liquids in gas processing plants, and domestic methanol production. 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 model contains adequate structure and is sufficiently flexible to examine the impact of a wide variety of petroleum-related

issues and policy options, in order to foster understanding of the petroleum refining and marketing industry as well as determine the effects of certain policies and regulations.

The PMM projects 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; 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 (PAD) District level.

D.5 Most Recent Model Update:

October 1996

D.6 Part of Another Model?

National Energy Modeling System (NEMS)

D.7 Model Interfaces:

Receives information from the International, Natural Gas Transmission and Distribution, Oil and Gas Supply, Renewable Fuels, Electricity Market, Residential, Commercial, Industrial, and Transportation Models. Delivers information to each of the models listed above plus the Macroeconomic Model.

D.8 Official Model Representative:

Thomas White
Office of Integrated Analysis and Forecasting
Oil and Gas Analysis Branch
(202) 586-1393

D.9 Documentation:

EIA Model Documentation: Petroleum Market Model of the National Energy Modeling System (NEMS), December 1996. (DOE/EIA-M059).

D.10 Archive Media and Installation Manual

Archived as part of the NEMS AEO97 production runs.

D.11 Energy System Described:

Petroleum refining industry and refined products market.

D.12 Coverage:

Geographic: Twelve domestic crude oil production regions (East Coast, Gulf Coast, Mid-Continent, Permian Basin, Rocky Mountain, West Coast, Atlantic Offshore, Gulf Offshore, Pacific Offshore, Alaska South, Alaska North, Alaska Offshore); five refining regions (PAD Districts I-V); nine market regions, the Census divisions (New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, Pacific)

Time Unit/Frequency: Annual, 1990 through 2015

Products: LPG, traditional motor gasoline, traditional high oxygen motor gasoline, reformulated motor gasoline, reformulated high oxygen motor gasoline, M85, E85, jet fuel, distillate fuel oil, highway diesel, low-sulfur residual fuel oil, high-sulfur residual fuel oil, petrochemical feedstocks, asphalt/road oil, marketable coke, still gas, other.

Refinery Processes: crude distillation, vacuum distillation, delayed coker, fluid coker, visbreaker, fluid catalytic cracker, thermal cracker, hydrocracker-dist, hydrocracker-resid, solvent deasphalter, resid desulfurizer, FCC feed hydrofiner, distillate HDS, naphtha hydrotreater, catalytic reformer-450 psi, catalytic reformer-200 psi, alkylation plant, catalytic polymerization, pen/hex isomerization, butane isomerization, etherification, butanes splitter, dimersol, butylene isomerization, total recycle isomerization, naphtha splitter, C2-C5 dehydrogenator, cyclar unit, hydrogen plant, sulfur plant, aromatics recovery plant, lube + wax plants, FCC gasoline splitter, gas/H2 splitter, stream transfers, fuel system, steam production, power generation.

Crude Oil: Alaska low sulfur light, Alaska mid sulfur heavy, domestic low sulfur light, domestic mid sulfur heavy, domestic high sulfur light, domestic high sulfur heavy, domestic high sulfur very heavy, imported low sulfur light, imported mid sulfur heavy, imported high sulfur light, imported high sulfur heavy, imported high sulfur very heavy.

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

D.13 Modeling Features:

Model Structure: FORTRAN callable subroutines which update the linear programming matrix, re-optimize, extract and post-process the solution results, update system variables, and produce reports.

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

Special Features: Choice of imports or domestic production of products is modeled, capacity expansion is determined endogenously, product prices include fixed and environmental costs, oxygenated and reformulated gasolines and low-sulfur diesel fuel are explicitly modeled.

D.14 Non-DOE Input Sources:

Information Resources Inc. (IRI), WORLD model data, National Petroleum Council, ICF Resources, Oil and Gas Journal.

D.15 DOE Input Sources:

Forms:

EIA-14	Refiners' Monthly Cost Report
EIA-182	Domestic Crude Oil First Purchase
EIA-782A	Monthly Petroleum Product Sales
EIA-782B	Reseller/Retailer's Monthly Petroleum Product Sales
EIA-782C	Monthly Petroleum Products Sold into States for Consumption
EIA-759	Monthly Power Plant Report
EIA-810	Monthly Refinery Report
EIA-811	Monthly Bulk Terminal Report
EIA-812	Monthly Product Pipeline Report
EIA-813	Monthly Crude Oil Report
EIA-814	Monthly Imports

EIA-817	Monthly Tanker and Barge Movement
EIA-820	Annual Refinery Report
EIA-826	Monthly Electric Utility Sales
EIA-856	Monthly Foreign Crude Oil Acquisition
EIA-867	Annual Nonutility Power Producer Report
FERC-423	Monthly Report of Cost and Quality of Fuels for Electric Plants

In addition to the above, information is obtained from several Energy Information Administration formal publications: *Petroleum Supply Annual*, *Petroleum Supply Monthly*, *Petroleum Marketing Annual*, *Petroleum Marketing Monthly*, *Fuel Oil and Kerosene Sales*, *Natural Gas Annual*, *Natural Gas Monthly*, *Annual Energy Review*, *Monthly Energy Review*, *State Energy Data Report*, *State Energy Price and Expenditure Report.*

D.16 Computing Environment:

Hardware:	RS 6000 POWER server 590
Operating System:	AIX version 3
Software:	AIX FORTRAN, OML
Memory Requirement:	4,000K
Storage Requirement:	34.7 MB
Estimated Run Time:	2,200 seconds in a full NEMS run (26 years)
Special Features:	None.

D.17 Independent Expert Reviews Conducted:

Independent reviews of the Component Design Report of the PMM were conducted by:

A.S. Manne, ASM Consulting Services, July 1992
A.S. Manne, ASM Consulting Services, September 1992

D.18 Status of Evaluation Efforts by Sponsor:

None.

APPENDIX E

Data Quality

APPENDIX E. Data Quality

E.1 Quality of Distribution Cost Data

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products are estimated as the average annual difference between retail and wholesale prices over the years 1984 through 1995[1]. The differences are based on **wholesale prices** in the producing Census division and **end-use prices** (which do not include taxes) in the consuming Census division. See Appendix F for a discussion of programs and input files used in estimating these markups.

Annual **wholesale prices** for all petroleum products are aggregated from state-level prices from the EIA-782A. The estimation and reliability of the EIA-782A data is discussed in the *Petroleum Marketing Annual 1995* (DOE/EIA-0487(95)). See Table E1 for inputs and sources.

With the exception of gasoline, non-utility distillate fuel, and jet fuel, **sectoral end-user prices** through 1993 are aggregated from prices from the State Energy Price and Expenditures Report 1993 (SEPER). The methodology behind these state-level sectoral prices are discussed in the *State Energy Price and Expenditures Report 1993* (DOE/EIA-0376(93)). One area of concern is the SEPER methodology for residual fuel transportation prices where the vessel bunkering prices are tied to State electric utility prices. This methodology is questionable because most utility residual fuel use is on the East Coast whereas vessel bunkering is concentrated on the Gulf and West Coasts.

Gasoline, jet fuel, and non-utility distillate prices are estimated as weighted averages using end-user prices from EIA-782A and sectoral consumption from the *State Energy Data Report* (DOE/EIA-0214(93) (SEDS).

Due to a two-year lag in the publication of the SEPER data, end-use price estimates for 1994 and 1995 are calculated using the same data series and methodology described in SEPER. The SEPER methodology uses prices from EIA-782A, FERC-423, EIA-759, and weights them with consumption volumes from SEDS. Refer to SEDS for a discussion of the reliability of consumption data and to Electric Power Annual 1995 (DOE/EIA-0348(95)) for a discussion or the reliability of electric utilities data from FERC-423 and EIA-759. Table E1 shows the data series used in the estimation of end-use prices.

[1] Transportation markups for kerosene are based on the difference between end-user kerosene prices and wholesale distillate prices.

Table E1. Sources of Markup Inputs

Products	Sectors	Data Series Inputs
Distillate	CM, IN, RS, TR	EIA-782A, SEDS
Jet Fuel	TR	EIA-782A, SEDS
Motor Gasoline	CM, IN, TR	EIA-782A, SEDS
Asphalt and Road Oil	IN	SEPER, EIA-782A, SEDS
Kerosene	CM, IN, RS	SEPER, EIA-782A, SEDS
Liquified Petroleum Gases	CM, IN, RS, TR	SEPER, EIA-782A, SEDS
Low Sulfur Residual Fuel	CM, IN	SEPER, EIA-782A, SEDS
High Sulfur Residual Fuel	TR	SEPER, EIA-782A, SEDS
Distillate	EU	SEPER, EIA-759, FERC-423
Low Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423
High Sulfur Residual Fuel	EU	SEPER, EIA-759, FERC-423

E.2 Quality of Tax Data

In the PMM, State and Federal taxes are added to the prices of gasoline, and distillate fuel, liquefied petroleum gas (LPG), jet fuel, ethanol and methanol in the transportation sector. State taxes are held constant in real terms while Federal taxes are deflated in each forecast year. The tax methodology was adopted starting with AEO95 because a tax trend analysis indicated that State taxes keep pace with inflation while Federal taxes do not.

The State taxes are added as Census division weighted averages which are based on the most recently-available State taxes. State taxes for jet fuel are from and unpublished spreadsheet from the Petroleum Marketing Division of EIA, while state taxes for ethanol and methanol are taken from The Clean Fuels

Report, April 1996, published by J.E. Sinor Consultants. State and Federal taxes for gasoline, transportation distillate, and LPGs are based on data from the Federal Highway Administration, but are modified to include other known changes to State taxes. The quality of the State level tax data is unknown but deemed reliable. Federal taxes, which were increased by 4.3 per gallon in 1993, are widely published, and deemed highly reliable.

See Appendix F for a description of programs and input files used in the estimation of historical taxes and taxes used in the price projections.

E.3 PMM Critical Variables

The PMM contains numerous variables and parameters. Some variables have greater impact on model results than others. The following is a list of variables that we believe has a high degree of influence on PMM results. It is provided to help users understand the critical factors affecting the PMM.

- World oil price
- Product demands
- Imported crude supply curves
- Imported product supply curves
- Domestic crude production
- Prices and available supplies of methanol, ethanol, MTBE, and other ethers
- Investment cost for capacity expansion
- Market shares for gasoline and distillate types
- NGL supply volumes

Most of these variables are provided by other models in the NEMS system. The investment cost and market share data are developed offline and read in to the PMM.

Tests on some of these variables are discussed in a separate appendix to this documentation, titled *Documentation of the Petroleum Market Model, Appendix: Model Developer's Report*. In an earlier effort, a detailed calibration was made, using the same refinery model technology database as in PMM, compared against the EIA Petroleum Supply Annual (PSA) for 1989.[2] This comparison indicated that the validation was quite good with total crude volumes from the model only 0.48 percent above actual PSA values and total production just 0.28 percent higher. A more complete comparison, including assumptions, can be found in the cited reference.

[2]"U.S. Detailed Refinery Model," Letter of October 20, 1993, from Martin Tallett of ENSYS to G. H. Harp of EIA.

APPENDIX F

Estimation Methodologies

APPENDIX F. Estimation Methodologies

F.1 Refinery Investment Recovery Thresholds

The calculation methodology for the capital investment recovery threshold values have been taken from a standard refinery industry reference.[1] The inside battery limits (ISBL) investment cost and labor costs for most of the processing unit types were obtained from a study by Bonner and Moore Associates.[2] The data for typical unit sizes and stream factors as well as supplementary investment and labor was obtained from the World Oil Refining, Logistics, and Distribution (WORLD) model.[3] A basic premise used in the PMM application is that the investment recovery value at the end of project life (PL) will equal site decommissioning cost, an expectation that seems to be widely shared in the petroleum industry.

The inside battery limits cost per barrel investment cost at the Gulf Coast (P) for each refinery process modeled was obtained from the cited data sources. The total investment cost (INV) was then calculated using the referenced methodology. Finally, the capital recovery threshold for each process was calculated.

Given that a Gulf Coast plant and equipment battery limits cost for an expansion of processing plant type I is $\boldsymbol{P_i}$ dollars per barrel per day of stream day capacity (This is assumed to include required storage facilities but not necessarily all mandated environmental systems.), then the nominal total plant and equipment cost at some arbitrary location would be

$$NTPE_i = P_i(1+U)(1+O) \quad \textbf{(1)}$$

where U = Utilities cost multiplier
O = Offsites multiplier

With construction occurring over a 3-year period at a constant rate, the present value of the nominal total plant and equipment is

$$PVNTPE_i = \frac{NTPE_i}{3}\Sigma_{j=1}^{3}(1+DEF_i)^j \quad \textbf{(2)}$$

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[1]J.H. Gary and G.E. Handwerk, *Petroleum Refining: Technology and Economics* (New York: Marcel Dekker, 1975), Chapters 13 and 14.

[2]Bonner & Moore Associates, Inc., *A Capital Expansion Methodology Review of the Department of Energy's Petroleum Market Model*, prepared for the United States Department of Energy, Contract No. EI-94-25066 (Houston, TX, July 1994).

[3]Ensys Energy & Systems, Inc., *WORLD Reference Manual*, a reference for use by the analyst and management prepared for the United States Department of Energy, Contract No. DE-AC-01-87FE-61299 (Washington, D.C., September 1992).

where DEF = inflation rate during construction

The final land, plant, and equipment cost is

$$FLPE_i = PVNTPE_i(1+S)(1+C) \quad \textbf{(3)}$$

where S = Special costs multiplier (includes land)
C = Contingency cost multiplier

The total investment is

$$INV_i = (1+W) * FLPE_i \quad \textbf{(4)}$$

where W = Working capital multiplier

A multiplier called the plant depreciation factor or PDF, is used in the investment recovery calculations. It is merely the ratio of depreciable investment to total investment. More specifically, the numerator of the PDF is total investment less land, working capital, and supplies. The total Gulf Coast investment cost and depreciable investment fraction (PDF) as well as the fixed costs are presented in Table F4. The location factors, taken from working papers developed for the 1993 NPC refinery study, are presented in Table F2. In order to do this, several premises have been set in accordance with Table F1. The multipliers in Table F1 were obtained from the Gary and Handwerk reference. The variability of these factors is unknown. The INV values were pre-calculated in a worksheet so the recovery factors could be placed in the FORTRAN code while maintaining flexibility in changing the key volatile parameters such as required return on investment. The investment data are used for two different purposes in PMM: (1) the negative of the sum of the recovery factor and the fixed cost are entered into the objective row of the unit expansion vectors of the PMM LP to provide an investment decision criteria; i.e., the investment will occur to the extent that it is economic and (2) the basic investment cost (INV) multiplied by the location factor (L) and any appropriate environment factor is what must be multiplied by the LP expansion vector activity with the resulting products summed to provide entries for the CAPEXP matrix, i.e. the capital expenditure table, of the NEMS FORTRAN common block.

Table F1. Investment Multiplier Values

Multiplier	Value
U	0.075
O	0.15
DEF	0.03
C	0.15
S	0.04
W	0.10

The capital recovery threshold is calculated from:

$$CRT_{i,j} = \frac{INV_i \times (L_j + E) \times (U_{R,PL} - PDF_i \times \frac{TR_j}{PL \times 365})}{(1 - TR_j)} \quad \textbf{(5)}$$

where,

$CRT_{i,j}$ = The daily investment recovery required for processing unit type I at location j, $/bbl

INV_i = The investment required for processing unit type I on the Gulf Coast, $/bbl

L_j = Location factor for PAD District j

E = Investment factor for environmental capital expenditure

PDF_i = Plant depreciation factor (fraction of investment that may be depreciated) for processing unit type I

TR_j = Effective combined income tax rate in PAD District j

R = Investment return rate, fraction

PL = Plant life, years

Table F2. Location Index (J) and Location Factors

PAD District	Location Factor
I	1.2
II	1.2
III	1.0
IV	1.2
V	1.2

when R > 0, then

$$U_{R,PL} = \frac{R}{365 \times (1 - (1 + \frac{R}{365})^{-PL \times 365})} \quad \textbf{(6)}$$

otherwise,

$$U_{R,PL} = \frac{1}{PL \times 365} \quad \textbf{(7)}$$

Also,

$$TR_j = TRF + TRS_j - TRF x TRS_j$$

where

TRF = Federal income tax rate

TRS_j = Average state income tax rate for PAD District j, weighted by crude oil charge

Note that an investment tax credit can be added to this investment model by decreasing the INV by the applicable fraction.

The reader may verify his understanding of the investment equations from a simple example. Calculating the capital recovery required to expand the crude oil distillation tower capacity in PAD District III by one barrel per day for a 15 percent return over a 15-year plant life with a combined income tax rate of 44.2 percent with no allowance for collateral environmental cost,

$CRT_{ACU,I}$ = \$0.40/day.

Refinery Unit Fixed Cost Factor

The fixed cost which, in conjunction with the capital recovery threshold forms the threshold for expansion investment decisions, for processing unit type I is calculated from:

$$FC_i = \frac{1}{365}[B_i + PVNTPE_i \sum_{j=1}^{6} F_j] \quad \textbf{(8)}$$

where

B = Operations labor, $/year/BBL/day

the 6 "F" multipliers are shown in Table F3.

Table F3. Fixed Cost Multiplier Values

Multiplier	Value
1, Insurance	0.005
2, Local tax rate	0.01
3, Maintenance	0.04
4, Supplies	0.002
5, Overhead	0.015
6, Environment	0.02

The labor charge, B, and the overhead multiplier is taken from the WORLD model. The first 4 multipliers was obtained from the Gary and Handwerk reference. The environment base multiplier results from analyst judgement. The 1993 NPC study estimates the new environmental refinery operation and maintenance cost as about one third of base operations and maintenance over the 1991-1995 time period. Gary and Handwerk estimate the maintenance factor to vary between 3% and 8%, 4% was used because the trend is for refineries to increase operating efficiency over time. Variability of the other factors is unknown.

Table F4. Refinery Investment Recovery Data
($1991)

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
Crude oil tower	ACU	$565	0.775	$0.12
Vacuum unit	VCU	$895	0.775	$0.18
Solvent deasphalting	SDA	$1,909	0.775	$0.40
Delayed coker	KRD	$4,308	0.775	$0.85
Fluid/flexicoker	KRF	$5,502	0.775	$1.10
Visbreaker/TCC	VBR	$1,390	0.775	$0.29
Naphtha hydrotreater	NDS	$1,100	0.775	$0.24
Distillate desulfurizer	DDS	$1,622	0.775	$0.35
FCC feed hydrofiner	FDS	$1,971	0.775	$0.41
Residuum desulfurizer	RDS	$4,525	0.775	$0.95
Gas oil hydrocracker	HCR	$5,463	0.775	$1.14
Residuum hydrocracker	HCV	$7,300	0.775	$1.49
Naphtha hydrotreater	HCN	$3,347	0.775	$0.69
Lube and wax units	LUB	$13,514	0.775	$2.75
Gas oil dewaxer	DEW	$1,353	0.775	$0.30
Prefrac hi density ATF	JFP	$2,168	0.775	$0.76
Hi density ATF HD unit	HDN	$14,949	0.775	$3.11
HP Semi regen REFORMER	RFH	$1,810	0.775	$0.42
LP Cyclic reformer	RFL	$2,232	0.775	$0.50
LP Continuous reformer	RFC	$2,655	0.775	$0.59
Naphtha splitter	SPL	$724	0.775	$0.15
C3/C4 dehydrogenation	OLE	$11,101	0.775	$2.34
Fluid cat cracker	FCC	$3,656	0.775	$0.75
FCC fractionation	FGS	$579	0.775	$0.11
Alkylation unit	ALK	$5,999	0.775	$1.32
Polymerization unit	CPL	$1,882	0.775	$0.42
Dimersol unit	DIM	$2,606	0.775	$0.56
Aromatics recovery	ARP	$3,041	0.775	$0.67
Pen/Hex Isomerization	PHI	$3,620	0.775	$0.98
Butane isomerization	C4I	$5,213	0.775	$1.46
Total recycle isom	TRI	$5,642	0.775	$1.17
Cyclar unit	CYC	$10,736	0.775	$2.13

Processing Unit	Unit Index	INV (Dollars per bbl/d)	PDF	Fixed Cost ($/bbl)
C4E based oxy unit	ETH	$5,744	0.775	$1.20
C5E+ based oxy unit	ETM	$10,241	0.775	$2.08
Merchant MTBE	MBM	$37,332	0.775	$7.39
Cryogenic C2 fractionator	ETS	$1,485	0.775	$0.33
C2E - C4E Dimerization	C24	$10,682	0.775	$2.51
Hydrogenate NC5E/NC6E	C56	$2,020	0.775	$1.30
H2 Steam ref bfoe/d	H2P	$27,499	0.775	$5.62
H2 Partial Ox bfoe/d	H2X	$27,378	0.775	$5.40
Sulfur, S tons/day	SUL	$168	0.775	$0.04
Steam gener, lbs/hr	STG	$60	0.775	$0.01
Power generation, MKW	KWG	$7	0.775	$0.00
M Dist Furfural trting	FEX	$1,722	0.775	$0.35
M Dist deep hydrotrt	DHT	$2,392	0.775	$0.48
Methanol unit	MOH	$25,681	0.775	$3.41

F.2 Gas Plant Models

The gas plant models for each PAD District is maintained on the spreadsheet 'NGL.WK1' maintained within EIA by the Oil and Gas Analysis Branch. These models require gas plant wet gas volumes as input. In order to accommodate the information available, dry gas production volume, and permit gas plant activity to be driven by dry natural gas demand, factors are applied to the dry gas demand volumes to calculate imputed volumes of processed wet gas. In PADD V, the PMM models only the California gas plants. Although Alaska produces and processes a considerable volume of natural gas, it is nearly all used for reinjection with some NGL dumped into the crude pipeline with the exception of modest volumes of southern Alaska production. The southern Alaska production does have a local NGL market with much of the dry gas shipped out as LNG. In any case, the PAD District V refinery industry is virtually unaffected by Alaska NGL production. Thus, the PMM aggregate gas plant includes California only. Gas residue volumes are not available to the PMM but total dry gas volumes by PAD District are. This information is in the NEMS common block region. Specifically, the total dry gas volumes are available in:

Common block: NGTDMOUT

Variable matrix: PRNG_PADD(PADD,YEAR), BCF

Description: Total dry gas produced including plant fuel and lease fuel (P&L) for PAD District 'PADD' in year 'YEAR' excluding Alaska.

Each of the five values must be multiplied by a factor to obtain an estimate of the corresponding wet gas that is processed by the gas plants; i.e. the total dry gas volumes are multiplied by the ratio of processed wet gas to total dry gas production. These ratios are derived from 1993 data[4] so that data variability is unknown. The five multipliers are shown in Table F5.

Table F5. Total Dry Gas Multiplier

PAD District	Multiplier
I	0.4536
II	0.7659
III	0.7572
IV	1.0136
CA	0.7745

[4]Energy Information Administration, *Natural Gas Annual 1993*, DOE/EIA-0131(93), (Washington, DC, October 1994).

The multiplier for PAD District I is low because relatively little of the modest PAD District I gas production is processed beyond field decontamination. The multiplier is high for PADD IV because a great deal of Utah gas production is reinjected for field pressure maintenance. This reinjected gas is not counted in total dry gas production.

The NGL extraction is allowed to occur at a minimum, maximum, or average level. Complete ethane rejection is allowed with a processing credit for each barrel rejected. Propane rejection occurs in U.S. gas plants but to an unknown extent. The model allows propane rejection up to one fourth of the propane volume. The basic model structure is devised from the Pace Consultants annual petrochemical report[5]. The liquids extraction data have been calculated by averaging actual liquid extraction volumes from the 4-year period 1990 - 1993[6] as well as obtaining minimum and maximum values. The coefficients were then normalized. The minimum and maximum values seem to suggest the variability of the data but the reader is cautioned that statistically based models, as opposed to engineering models, may understate processing flexibility. Furthermore, the gas business is not statistical. It is driven by technology and ecomomics, i.e. history is suspect as a basis for such values.. The model for PAD District III is shown in the following table. Models for the other PAD Districts are similar except the extraction coefficients differ.

Table F6. Gas Plant Model for PAD District III

	MIN	MAX	AVG	ETH	PRO	Row Type	RHS
Wet Nat. Gas (MMcf)	-1.000	-1.000	-1.000			=	0
Dry Gas (MMcf)	0.945	0.938	0.941	0.002	0.002	=	+
Ethane (bbl)	14.070	14.332	14.562	-1.000			
Propane (bbl)	11.165	11.628	11.782		-1.000		
I-Butane (bbl)	4.375	4.776	4.693				
N-Butane (bbl)	2.506	4.409	3.349				
Nat. Gasoline (bbl)	7.025	7.310	7.286				
Volume Loss (MMcf)	-39.058	-42.394	-41.613	0.998	0.998		
Fuel (MMcfl)	-0.037	-0.040	-0.040				
Oper. Cost ($)	-115.07	-124.82	-122.51				
Oper. Cost ($/bbl)				5.88	2.94		
Capacity limit (bbl/d)					1.000	≤	+

[5]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, September 1989).

[6]Energy Information Administration, *Natural Gas Annual 1991*, DOE/EIA-0131(91), (Washington, DC, October 1992) and similarly, the Natural Gas Annuals for 1986-1990.

Table F6 differs from the implemented model in three respects. Propane rejection is controlled via column limit in the LP rather than as a row limit and the operating costs are merely entered into the objective function row rather than occupying two rows as the above depiction suggests. Of course these things are shown in the above form for the sake of clarity. The major difference is that the wet gas balance row is an equal zero row in the LP representation. There is a column representing pseudo purchases of wet gas with a plus one in the wet gas balance row and minus the forecasted gas price in the objective function row. Of course, this column is fixed at the determined level of processed wet gas.

F.3 Chemical Industry Demand for Methanol

Since the PMM includes methanol plant models in each PAD District representing all U.S. methanol capacity, U.S. chemical industry demand (demand other than for MTBE/TAME feedstock and neat fuel) is a required input. The Pace Consultants make long range forecasts of the chemical industry demand[7]. Their forecast is:

Table F7. Chemical Industry Demand for Methanol

Year	Demand (Mbbl/d)	Year	Demand (Mbbl/d)
1990	66.7	2003	89.4
1991	73.7	2004	93.4
1992	72.0	2005	97.6
1993	73.4	2006	102.0
1994	74.8	2007	106.6
1995	76.6	2008	111.4
1996	78.0	2009	116.4
1997	79.5	2010	121.6
1998	81.0	2011	127.1
1999	82.6	2012	132.8
2000	84.2	2013	138.8
2001	85.8	2014	145.0
2002	87.6	2015	151.6

The methanol plant model in each PAD District is represented by a single column activity that consumes natural gas and produces methanol. Two additional transportation activities allow the methanol produced to be transported to the refining region for production of MTBE/TAME and/or splash blending in gasoline or sent to meet the national demand for methanol by chemical plants. The model also allows capacity expansion of the methanol plant.

[7]Pace Petrochemical Service, *Annual Issue*, (Houston, TX, October 1992).

F.4 Estimation of Refinery Fixed Costs

The marginal prices computed in the PMM by the use of the Simplex algorithm cannot be used directly to determine the wholesale (refinery gate) price because they do not include the refinery source environmental costs. These are expenditures incurred to satisfy regulations related to air and water pollutants, solid waste management, and health and safety controls at refineries. Related costs are based on estimates of capital investment, one-time, and operation and maintenance expenses provided in the 1993 National Petroleum Council Study.[8]

The NPC Study provides PAD District level estimates of capital, one-time, and operating and maintanence expenses over three time periods: 1991-1995, 1996-2000, and 2000-2010. Operation and maintainence expenses existing prior to 1996 are not used as they are already reflected in the fixed operating cost estimates. The NPC estimates were converted to an annual average cost per barrel of distillation capacity for inclusion as a fixed cost (Table F8).

The underlying NPC analysis reflects the actions described below:

Air related costs include attainment of ambient air quality standards (Title I of the Clean Air Act Amendments), hazardous air pollutants (Title III, MACT standards), and permits (Title V)[9].

Water related costs include technology required to satisfy toxicity requirements of the National Pollution Discharge Elimination System (NPDES) authorized by the Clean Water Act. Costs for additional measures to protect groundwater are also assumed[10].

Solid waste related costs include remediation of contaminated soil at refineries sites, recovery and monitoring wells, the listing of additional refinery wastes as hazardous, the closing of unlined impoundments, and an assumed phased replacement of half the tanks over 40 years of age[11].

Safety and health related costs includes an assumed phase-out of hydrofluoric alkylation (hf) plants due to the classification of hf as a highly hazardous material. Small costs associated with implementing process hazards analysis are also contained in the NPC estimates[12].

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

[9]Ibid, Section V-9-12.

[10]Ibid, Section V-13.

[11]Ibid, Section V-16.

[12]Ibid, Section V-19.

For comparative purposes NPC's estimated capital and OTE costs aggregated over 1991-2010 results in total environmental investments of $43.5 billion. The NPC sum can be compared to estimated investments published by the API[13], by adding the API estimates for individual legislation that are consistent with NPC. The NPC total falls in the middle of the range of API investments of $19.4 to $60.0 billion.

Table F8. Refinery Source Envrionmental Costs, by PAD District

(1987 $/bbl)

	PAD District I	PAD District II	PAD District III	PAD District IV	PAD District V
Annual Environmental Cost	0.48	0.47	0.38	0.70	0.48

A methodology was developed to allocate refinery source environmental costs to the marginal prices of light products (LPG, gasoline, kerosine, jet fuel, No. 2 heating oil, and low sulfur highway diesel) thus including fixed costs in the prices reported at the refinery gate. The heavy products (residual oil, petrochemical feedstocks, asphalt, and other) are priced at their marginal cost due to competition from other fuels. Fixed refinery costs in each PAD District are estimated as the sum of fixed operating costs, return on assets, and environmental costs associated with controlling pollution at refineries (Table F8). The average annual cost is applied to all years and is recovered in the prices of light products only. A variable cost methodology was investigated but was deemed to be an unneccessary complication. The costs for each five year time period were estimated to vary by less than one-cent per gallon but would require significant changes to the model.

The methodology for allocating costs among light products is based on the concept of marginal cost and was developed from a similar approach used by the Gas Research Institute (GRI).[14] The steps used are as follows:

(1) Determine the environmental investment and operating costs.
(2) Determine the marginal revenue from the LP solution that will recover the marginal cost (the product of the marginal price of each product times the production volume).
(3) Calculate ratios that will apportion the environmental costs to the light products marginal prices.
(4) Use the ratios from (3) to scale the marginal prices to refinery gate wholesale prices.

[13]The sum of the initial cost estimates in *Costs to the Petroleum Industry of Major New and Future Federal Government Environmental Requirements*, American Petroleum Institute, Discussion Paper #070, (Washington, D.C., October 1991), Tables ES-1 and ES-2. Aggregate estimates exclude product specification and off-site costs, and utilized minimum RCRA reauthorization.

[14]Gas Research Institute, "U.S. Refining Model Methodology", (May 1991).

Equations: First, marginal revenue is determined for each refining region R:

$REVLP(LP)_R = VALUE(LP)_R * VOLUME(LP)_R$

$REVHP(HP)_R = VALUE(HP)_R * VOLUME(HP)_R$

where:

VALUE(LP) is the marginal price for each light product (LP) that will bear the fixed cost

VALUE(HP) is the marginal price for each heavy product (HP) that will not bear the fixed cost

VOLUME(LP) is the production volume for each light product

VOLUME(HP) is the production volume for each heavy product

$TOTREV_R = REVLP(LP)_R + REVHP(HP)_R$

Second, the total revenue required, including the fixed costs, FIXCOST is determined:

$NTOTREV_R = REVLP(LP)_R + REVHP(HP)_R + (FIXCOST_R * VOLUME)$

$NLTREV_R = NTOTREV_R - REVHP(HP)_R$

The last step is to calculate the refinery gate price for each light product

$GATEPR(LP)_R = (NLTREV_R / REVLP(LP)_R) * VALUE(LP)_R$

F.5 Estimation of Distribution Costs

Costs related to distributing petroleum products to end-users are incorporated by adding fixed transportation markups to the wholesale prices which include the variable and fixed refinery costs. Transportation markups for petroleum products are estimated as the average annual difference between retail and wholesale prices over the years 1984 through 1995. The differences are based on wholesale prices in the producing Census division and end-use prices (which do not include taxes) in the consuming Census division. Wholesale prices are aggregated from State-level prices from the EIA-782A. Sectoral end-user prices are aggregated from State-level prices from the State Energy Price and Expenditures Report (SEPER) 1993. End-use prices after 1993 are estimated according to the SEPER's methodology. Computer programs and data files used to estimate transportation markups are discussed below.

Data-Reading Programs

The following programs access EIA survey data and should be updated each year. Member names of SAS data sets are given in parenthesis.

Program: **PRJ6007.NEMS.MARKUP.WHOLSALE**

Files Read:
BBM6007.A.SASDB.STATE.AB
(IMPSTATA)
BBM6007.A.SASDB.STATE.AB9495
(IMP94A)
(IMP95A)
PRJ6007.NEMS.MARKUP.SASDB
(REGIONS)
(WHOLSALE)

This program reads a databases containing State-level refiner wholesale prices from the EIA-782A. A separate file is read for data prior to 1994 because the 782 data was kept in a different data system. Wholesale prices for asphalt and road oil, distillate fuel, gasoline, jet fuel, kerosene, liquefied petroleum gases, and residual fuel oil are aggregated into Census division prices (cents/gallon) and output to the NEMS database for other markup programs to access. Data available in March.

Program: **PRJ6007.NEMS.MARKUP.EIA782.READ**

Files Read: BBM6007.A.SASDB.STATE.AB9495
(IMP94B)
(IMP95B)
PRJ6007.NEMS.MARKUP.SASDB
(REGIONS)
(PRODE)

This program updates retail prices on the NEMS database using the most recent data from the EIA-782A contained in IMP94B and IMP95B. The State-level prices for gasoline, distillate, kerosene, jet fuel, high and low sulfur residual fuel, and liquefied petroleum gases for the most recent 2 years, 1994 and 1995, are aggregated into regional prices and added to data for previous years (using PRODE). The program is updated by revising files and incrementing YEAR in line 82. Contact the Petroleum Marketing Division of the Office of Oil and Gas concerning the EIA-782 data which is available in March.

Program: PRJ6007.NEMS.MARKUP.GDP87

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(GDP87CH)

This program updates the GDP deflators in the NEMS database. Program should be rerun after adding most recent year's deflator.

Program: PRJ6007.NEMS.MARKUP.CREATE.CONFAC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(CONVER84 through CONVER95)

This program provides annual conversion factors for each product. Factors for the most recent year of the SEPER's should be added to the data. These conversion factors are accessed by the SEPER.READ programs. The lpg factor is updated based on the upcoming SEDS (information available in April).

Program: PRJ6007.NEMS.MARKUP.SEPER.READ

Files Read: PRJ6356.SEPER.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(CONVER84 through CONVER95)
(STATE84 through STATE94)

This program reads State-level prices by sector from SEPER-1993 and puts them into the NEMS database. Prices are accessed for the following products:

gasoline (mg)
distillate (df)
kerosene (ks)
residual fuel (rf)
liquefied petroleum gases (lg)
jet fuel (jf)
asphalt and road oil (ar)
petrochemical feedstocks (fs)
naphtha feedstocks (fn)
other feedstocks (fo)

The program is set up to read only one year of data at a time. The data is available in September. The program should be rerun for historical years back to 1984 since historical data are sometimes revised in SEPER's. Each year's data can be updated by uncommenting the appropriate line between 15 and 21. The price series is read from the SEPER's database with 1984 prices at location 211 and consecutive years at intervals at 14 (1985 at 225, and so on). The appropriate lines should also be uncommented between 38 and 44 and between 61 and 67.

Program: **PRJ6007.NEMS.MARKUP.READ.F759**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(REGIONS)
(E759Y85 through E759Y95)
PRJ6944.F759.MASTER95

This program reads monthly volumes of distillate, low and high sulfur residual fuel consumed by electric utilities from EIA-759. The volumes are by State and are in gallons. The program annualizes the volumes and assigns them to Census divisions.

Program: **PRJ6007.NEMS.MARKUP.READ.F423**

Files Read: PRJ6501.F423.EXTR1984.REVGAS
PRJ6501.F423.EXTR1985.REVGAS
PRJ6501.F423.EXTR1986.REVGAS
PRJ6501.F423.EXTR1987.REVGAS
PRJ6501.F423.EXTR1988.DATA

PRJ6501.F423.EXTR1989.DATA
PRJ6501.F423.EXTR1990.DATA
PRJ6501.F423.EXTR1991.DATA
PRJ6501.F423.EXTR1992.DATA
PRJ6501.F423.EXTR1993.FINAL
PRJ6501.F423.EXTR1994.FINAL
PRJ6501.F423.EXTR1995.DATA
PRJ6007.NEMS.MARKUP.SASDB
(EUSTATE)
(UTDIV)

This program reads State-level quantities and costs of distillate, and high and low sulfur residual fuel consumed by electric utilities from FERC Form 423. The quantities and costs are converted to a trillion Btu basis and assigned to Census divisions. Preliminary data available in April.

Program: **PRJ6007.NEMS.MARKUP.ARVOL**

Files Read: PRJ6356.SEDS.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(ARVOL84 through ARVOL93)

This program reads industrial asphalt and road oil volumes from SEDS. The program is updated by accessing the most recent SEDS file and adding another output file similar to ARVOL93. The location of the volume should be incremented by 14 (@329+14). Data was not available in April.

Program: **PRJ6007.NEMS.MARKUP.KEROVOL**

Files Read: PRJ6356.SEDS.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(KERVOL84 through KERVOL93)

This program reads kerosene consumption in the residential, commercial, and industrial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to KERVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **PRJ6007.NEMS.MARKUP.GASVOL**

Files Read: PRJ6356.SEDS.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(GASVOL84 through GASVOL93)

This program reads gasoline consumption in the transportation, commercial, and industrial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to GASVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **PRJ6007.NEMS.MARKUP.LPGVOL**

Files Read: PRJ6356.SEDS.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(LPGVOL84 through LPGVOL93)

This program reads gasoline consumption in the transportation, residential, and commercial sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to LPGVOL93. The location of the volume should be incremented by 14 (@329+14).

Program: **PRJ6007.NEMS.MARKUP.RSVOL**

Files Read: PRJ6356.SEDS.PUBLIC93.DATA
PRJ6007.NEMS.MARKUP.SASDB
(RSVOL84 through RSVOL93)

This program reads gasoline consumption in the commercial, industrial, and transportation sectors from SEDS. To update - access the most recent SEDS file and add another output file similar to RSVOL93. The location of the volume should be incremented by 14 (@329+14).

Markup Estimating Programs

All "CALC" programs calculate markups as the difference between a products retail and wholesale price in each Census division and sector. The estimated markups are output to PRJ6007.NEMS.MARKUP.SASDB in 1987 dollars per trillion Btu. The output file from each program contains the variables PRODPMM, SECTOR, CENDIV, MEAN, AND STDERR.

Census Division "99" represents national data and Sector "ZZ" represents all sectors. The following table describes the source programs for petroleum product markups:

Table F9. Markups Output

Products	Sectors	Markup Program	File Name on MARKUP.SASDB
DS	CM, IN, RS, TR, ZZ	PMM.CALC	MARKPMM
JF	TR, ZZ	PMM.CALC	MARKPMM
MG	CM, IN, TR, ZZ	PMM.CALC	MARKPMM
AR	IN, ZZ	ASRO.CALC	MARKAR
KS	CM, IN, RS, ZZ	KERO.CALC	MARKOTH1
LG	CM, IN, RS, TR, ZZ	LPG.CALC	MARKLPG
RL	CM, IN	RESID.CALC	MARKRL
RH	TR	RHTR.CALC	MARKRH
DS	EU	ELECUTIL.CALC	MARKELEC
RL	EU	ELECUTIL.CALC	MARKELEC
RH	EU	ELECUTIL.CALC	MARKELEC

Program: **PRJ6007.NEMS.MARKUP.PMM.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(GDP87CH)
(GASVOL84 through GASVOL93)
(CONVER84 through CONVER93)
(RGAL82)
(MGBTU)
(MARKPMM)

This program uses retail gasoline, distillate, and jet fuel prices and volumes originating from the EIA-782A. Commercial and industrial gasoline prices are estimated by weighting the EIA-782 end-user (transportation) prices with SEDS volumes for these two sectors. Commercial and industrial gasoline volumes for 1993 are used to represent 1995 and 1995, since SEDS stops with 1993 data. Distillate and gasoline markups are

estimated as the average annual difference between end-use and wholesale prices for the years 1984 forward. Due to a break in the data trend, jet fuel markups are based on data starting in 1986.

To update: After updating "data" programs, revise this program to utilize more recent SEDS volumes by adding another data set that reads GASVOL94. Use CONVER96 and increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.ASRO.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(PRODE)
(ARVOL93)
(GDP87CH)
(CONVER84 through CONVER95)
(RGAL82)
(ARBTU)
(MARKAR)

This program uses State-level asphalt and road oil prices to the industrial sector from SEPER's through 1993. End-use prices for 1994 and 1995 are estimated using the 1994 and 1995 changes in the EIA-782 high sulfur residual fuel prices. Prices for each Census division are calculated using 1993 volumes from the SEDS. Estimates for 1994 and 1995 are weighted using 1993 volumes. Markups are estimated as the average annual difference between end-use and wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE94, use ARVOL94 and CONVER94, and increment all year dependent formulas by first changing .

Program: PRJ6007.NEMS.MARKUP.KERO.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(PRODE)
(KEROVOL93)
(GDP87CH)

(CONVER93)
(KEROGAL)
(KEROBTU)
(MARKOTH1)

This program uses State-level kerosene prices to the residential, commercial, and industrial sectors from SEPER's through 1993. End-use prices for 1994 and 1995 are estimated using the 1994 and 1995 changes in the EIA-782 distillate prices. Prices for each Census division are calculated using 1993 volumes from the SEDS. End-use price estimates for 1994 and 1995 are weighted using 1993 volumes. Markups are estimated as the average annual difference between kerosene end-use and distillate wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE94, use KERVOL94 and CONVER96, and increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.RESID.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(RSVOL93)
(GDP87CH)
(CONVER84 through CONVER95)
(RSGAL)
(RSBTU)
(MARKRL)

This program uses State-level residual fuel prices to the commercial, and industrial sectors from SEPERS through 1993. End-use prices for 1994 and 1995 are estimated using the 1994 and 1995 changes in the EIA-782 low sulfur residual fuel prices. Commercial and industrial prices for each Census division are calculated using 1992 volumes from SEDS. Price estimates for 1994 and 1995 are weighted using 1993 volumes. Residential prices are estimated using 1994 and 1995 EIA-782 consumption volumes. Markups are estimated as the average annual difference between low sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1984 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE94, use RSVOL94 and CONVER94, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.RHTR.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(PRODE)
(REGIONS)
(EUSTATE)
(RSVOL93)
(GDP87CH)
(CONVER95)
(RSTRGAL)
(RSTRBTU)
(MARKRHTR)

This program uses State-level residual fuel prices to the transportation sector from SEPERS through 1993. End-use prices for 1994 and 1995 are estimated using average residual fuel prices to electric utilities according to SEPER's methodology. The average Census division prices to utilities are multiplied by the ratio of national high sulfur price from the EIA-782 to the national residual fuel price to utilities. Prices for each Census division are calculated using 1993 volumes from SEDS. End-use price estimates for 1994 and 1995 are weighted using 1993 volumes. Markups are estimated as the average annual difference between high sulfur end-use prices and aggregate residual fuel wholesale prices for the years 1987 forward.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE94, use RSVOL94 and CONVER96, and increment all year dependent formulas.

Program: **PRJ6007.NEMS.MARKUP.LPG.CALC**

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(PRODE)
(REGIONS)
(LPGVOL93)
(GDP87CH)
(CONVER93)
(LPGGAL)
(LPGBTU)
(MARKLG)

This program uses State-level SEPER's prices for liquefied petroleum gases to the commercial, industrial, transportation, and residential sectors through 1993. The 1994 and 1995 prices for all sector's are the 782 sectoral prices, because the 782 began carrying sectoral data in 1994. Markups are estimated as the average annual difference between end-user lpg prices and wholesale prices for the years 1985 forward. The average residential markups exclude 1989 data because of the price spike related to a heating oil crisis that winter.

To update: After updating "data" programs, revise this program to utilize more recent data. Add a data set STATE94 use LPGVOL94 and CONVER96. Since sectoral 782 prices are available starting in 1994, remove the sections estimating the weighted average prices based on 782 average end-user prices, and residential price growth rates. Increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.ELECUTIL.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE93)
(PRODE)
(REGIONS)
(UTDIV)
(E759Y84 through E759Y95)
(GDP87CH)
(CONVER84 through CONVER95)
(EURFRGAL)
(EURFBTU)
(MARKELEC)

This program uses State-level SEPER's prices for distillate, high sulfur, and low sulfur residual fuel to electric utilities through 1993. End-use prices for 1994 and 1995 are estimated using SEPER's methodology. The program breaks residual fuel consumption from the EIA-759 into high and low sulfur using a high/low sulfur breakout estimated from the FERC Form 423. The estimated high and low sulfur residual fuel volumes are used to estimate weighted average prices to the utility sector.

Markups are estimated as the average annual difference between prices to utilities and wholesale prices for the years 1984 forward. The average markup for high sulfur residual fuel in Census division 8 excludes all years but 1990 because of an anomalous trend.

To update: After updating "data" programs, revise this program to utilize more recent data. Add datasets CONVER96, and E759Y96.

Program: PRJ6007.NEMS.MARKUP.CREATE.FLATFILE

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(MARKPMM)
(MARKLPG)
(MARKRL)
(MARKRHTR)
(MARKOTH1)
(MARKAR)
(MARKELEC)
PRJ6007.MARKUP.MU1PRDS.D0806961
PRJ6007.NEMS.MARKUP.DOL95.D0806961

This program pulls together the markups for each product, transposes the data and outputs it to a file used by NEMS. Converts the markups into 1995 dollars and outputs to a file.

To update: Update the GDPCH87 deflator, GDPDEF95.

F.6 Estimation of Taxes

In the PMM, taxes are added to the prices of gasoline, transportation distillate fuel, transportation liquefied petroleum gas, and jet fuel. Taxes are also estimated for M85 (transportation methanol) and E85 (transportation ethanol). Weighted averages of the most recently-available State and Federal taxes are developed for each Census division. The State taxes are fixed in real terms; the Federal taxes decline at the rate of inflation (i.e., Federal taxes are fixed in nominal terms). Historical values are also calculated for gasoline and transportation distillate and added to historical end-use prices excluding taxes in order to develop a series with taxes included. The State taxes, by sector, product, and year, are contained in following file which resides in the default input directory:

MU2PRDS

The Federal taxes are read into the PMM from file

QDCRDCF

and are updated each forecast year by deflating the current value by the rate of inflation for that forecast year.

The following section traces the development of the taxes and lists the files used to produce both historical and forecast values. The historical data are developed on a monthly basis by State, then aggregated to volume-weighted annual averages by Census division. The outputs specified are members of the following SAS database unless otherwise stated:

PRJ6007.NEMS.TAX.SASDB

Program: **PRJ6007.NEMS.TAX.Dyymm**

Inputs: semi-annual tax information from the Federal Highway Administration and other sources

Outputs: STyymmS
STyymmM
where yymm refers to years 84 through 94, and months 01 and 07 (except for 1990 when the months are 01 and 08)

Sources:		
	gasoline	Federal Highway Administration
	diesel	Federal Highway Administration
	LPG	Federal Highway Administration
	jet fuel	EIA, Petroleum Marketing Division
	M85	Clean Fuels Report
	E85	Clean Fuels Report

State-level taxes are obtained from the Federal Highway Administration on a semi-annual basis (usually reflecting taxes as of January 1 and July 1), supplemented by information from the *Petroleum Marketing Monthly*. These data are entered into the above programs.

We assume that taxes remain at the same level for the 6 months following each semi-annual report, unless information on effective dates of tax changes is provided. Thus, the tax level reported for say, 9207, is kept at the same amount for 9208-9212. The file STyymmS contains data for 1 month, while the file STyymmM reproduces the results for the subsequent 6 months, taking into account tax changes to the extent that they are known.

Program: **PRJ6007.NEMS.TAX.CALC94**

(Old Version): **PRJ6007.NEMS.TAX.CALC93**

Inputs: STyymmM for years 1984 to current

IMPSTATB, a file containing State-level refiner and marketer prices for petroleum products
IMPSTATA, a file containing State-level sales of petroleum products, which are used as weights in calculating weighted averages
REGIONS, maps States to Census divisions
GDP87, GDP deflators for conversion to constant dollars

Outputs: STGAS_MO
STDES_MO

The CALC program pulls together the monthly tax information and calculates Federal, State, and total taxes by month and State in cents per gallon and dollars per million Btu for both nominal and constant 1987 dollars. Sales volumes and regional designations are added to facilitate volume weighting across time and regions as required. Gasoline and diesel files are calculated and output separately. The programs were adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **PRJ6007.NEMS.TAX.YRREG**
(Old version): **PRJ6007.NEMS.TAX.YRREG93**

Inputs: STGAS_MO
STDES_MO

Outputs: STGAS_YR
STDES_YR
CDGAS_YR
CDDES_YR

The YRREG program takes the State monthly tax files created in the CALC program and develops weighted average annual taxes by State, then averages across Census divisions and outputs annual average taxes by Census division. The Census division annual averages are used to develop historical end-use prices including taxes by adding the calculated taxes to ex-tax prices from the *Petroleum Marketing Monthly*. The program was adjusted to incorporate changes in the EIA-782 database starting with the 1994 data.

Program: **PRJ6007.NEMS.TAX.FORECAST**

Inputs: STGAS_MO
STDES_MO
STGAS_YR
STDES_YR

Outputs: GASCAST
DIESCAST

The FORECAST program uses the latest tax information, combined with the most recent year of sales data, and develops Census division weighted-average taxes which are used for the forecast. The latest tax information is in the file:

PRJ6007.NEMS.TAX.DCURR

The outputs include both nominal, constant 1987, and constant 1994 dollar denominations for both cents per gallon and dollars per million Btu.

PRJ6007.NEMS.TAX.FORECAST.E85
PRJ6007.NEMS.TAX.FORECAST.JET
PRJ6007.NEMS.TAX.FORECAST.LPG
PRJ6007.NEMS.TAX.FORECAST.M85

These programs perform the same function as the FORECAST program above, but for the transportation fuels indicated. The comparable data files are the following:

PRJ6007.NEMS.TAX.DLPGJET
PRJ6007.NEMS.TAX.DM85E85

(Old versions): **PRJ6007.NEMS.TAX.DLPGJET.Y94**
PRJ6007.NEMS.TAX.DM85E85.Y94

Program: **PRJ6007.NEMS.TAX.CREATE.FLATFILE**
(contains State tax data only)

Inputs: GASCAST
DIESCAST

Outputs: **PRJ6007.NEMS.TAX.TESTFILE**

This program takes the Census division taxes to be used in the forecast and creates a file that is used as input to the PMM.

F.7 Gasoline Specifications

The PMM models the production and distribution of four different types of gasoline: traditional, oxygenated, and reformulated. The following specifications are included in PMM to differentiate between traditional and reformulated gasoline blends: octane, oxygen content, Reid vapor pressure (Rvp), benzene content, aromatic content, sulfur content, olefin content, and the percent evaporated at 200and 300 degrees Farhenheit (E200 and E300).

Starting in 1998 the specifications for traditional gasoline reflect the Environmental Protection Agency's (EPA) "1990 baseline." These specifications prevent the quality of traditional 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 traditional 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 U.S. since January 1995. Beginning in 1998, the EPA will only certify reformulated gasoline using the "complex model," which allows refiners to specify reformulated gasoline based on emissions reductions either from their companies' 1990 baseline or from the EPA's 1990 baseline. 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." Specifications such as Rvp, aromatics, sulfur, and olefin content change in the year 2000 reflecting further emissions reductions required by CAAA90.

The CAAA90 provided for special treatment of California that would allow different specifications for oxygenated and reformulated gasoline in that State. In 1992, California requested a waiver from the winter oxygen requirements of 2.7 percent to reduce the requirement to a range of 1.8 to 2.2 percent. The PMM assumes that PAD District V refiners must meet the California specifications.

Annual Average Rvp Methodology

The annual average Rvp limits are derived based on existing summertime requirements and estimated wintertime levels. The assumed summer and winter Rvp specifications had been annualized by simple averaging using summer and winter weights provided by the EPA.[15] However the cost of reducing Rvp may not be a linear function. Therefore, utilizing the Petroleum Market Model, a methodology based on marginal costs was developed to compute an Rvp specification to represent the annual average. The PMM was configured to run two separate cases for summer and winter using the appropriate product specifications and demands for each season. The summer and winter marginal costs for gasoline obtained from the two runs were averaged (weighted by demand) to produce a target annual cost. The PMM (re-configured for annual demands) was then run iteratively, varying Rvp until the model produced marginal gasoline costs that were significantly similar to the target cost. The resulting Rvp specifications were then reduced by 0.3 psi to reflect pipeline requirements which are tighter than the EPA limits. The Rvp specifications used in the PMM are shown in Table F10.

Table F10. Estimated Annual Reid Vapor Pressure

Gasoline Market/Type	Simple Average		Annual Rvp in PMM	
	PADD I-IV	PADD V	PADD I-IV	PADD V
Traditional/Oxygenated	10.2/11.0	9.2/11.0	10.0/11.0	9.2/11.0
Reformulated/Reformulated-High Oxygen				
1998-1999	9.5/11.0	8.7/NA	8.7/11.0	8.2/NA
2000-Forward	9.1/11.0	8.7/NA	8.5/11.0	7.9/NA

The lower Rvp specifications in PAD District V reflect more stringent California limits which are imposed statewide.

Complex Model Standards for Motor Gasoline

The Environmental Protection Agency (EPA) has promulgated new regulations for reformulated motor gasoline that are designed to lower vehicle emission pollutants as required by the amended Clean Air Act of

[15]The summer weight of 0.396 and winter weight of 0.604 were provided by Dave Korrotney of EPA (313-668-5507).

1990[16]. The reformulated gasolines are designed to reduce vehicle emissions of toxic and ozone-forming compounds. Reformulated gasoline must be sold in certain regions where there are summertime ozone problems as well as in areas which opt into the program. Traditional gasoline may be sold elsewhere but it must not be more polluting than it was in 1990. These areas are discussed elsewhere in the documentation. Although The EPA has established some conventionally treated specifications, namely minimum oxygen content and maximum benzene content, the new conceptual aspect of the emission standards is that the reformulated gasoline must be blended in such a way that it meets maximum allowable emissions of volatile organic compounds (VOCs), nitrous oxides (NO_x), and toxics. These new motor gasoline standards are calculated by complex formulae based upon key properties of the gasoline blend. The new regulations cover Phase I (1 January 1995 through 31 December 1999) and Phase II (1 January 2000 and indefinitely afterwards). During Phase I the refiner must certify his reformulated gasoline to meet the new standards but, at his option, he may use a simpler EPA model rather than the complex EPA model until 1 January 1998. The model assumes that refiners will use the complex model beginning in 1998. Also, the refiner may meet the requirements for VOCs and NO_x on either a per gallon basis or on an average basis although some per gallon constraints still apply. The average basis has been incorporated into the model.

The NO_x and toxics emission standards for reformulated gasoline apply year-round whereas the VOCs standards apply only in the summer. The NO_x standard varies depending upon whether the VOCs standards apply, i.e. depending upon whether it is summer or winter. The VOCs standard for the north[17] is different from the VOCs standard applying to the south, greater volatility is allowed in the north. The Complex Model Averaged Standards are shown below in Table F11.

[16]Federal Register, Environmental Protection Agency, Regulation of Fuels and Fuel Additives;Standards for Reformulated and Conventional Gasoline; Final Rule, Part II, 40 CFR Part 80, (Washington, DC, 16 February 1994)

[17]For the sake of simplicity, we use the terms south and north to refer to EPA regions 1 and 2 respectively. Region 1 is covered by ASTM Class B while Region 2 is covered by Class C.

Table F11. Complex Model Standards

	Phase I 1995 - 1999	Phase II 2000+
VOC Reduction, %		
South	≥ 36.6	≥ 29.0
North	≥ 17.1	≥ 27.4
NO_x Reduction, %		
Summer	≥ 1.5	≥ 6.8
Winter	≥ 1.5	≥ 1.5
Toxics Reduction, %	≥ 16.5	≥ 21.5
Oxygen, wt%	≥ 2.1	≥ 2.1
Benzene, %	≤ 0.95	≤ 0.95

These standards were translated into traditionally configured specifications for blending motor gasoline. First, two winter specifications were developed, one for Phase I and one for Phase II. Of course, the VOCs standard was excluded from consideration. Then four summer specifications were created, a south set and a north set for Phase I and similarly for Phase II.

These sets were developed by use of a spreadsheet, developed by EPA, which calculates the VOCs, NO_x, and Toxics of a reformulated gasoline as a function of the 'conventional' properties of the gasoline, i.e. as a function of Rvp, sulfur content, oxygen content, aromatics content, olefins content, benzene content, percent evaporation at 200 degrees Fahrenheit (E200), and percent evaporated at 300 degrees Fahrenheit (E300). The approach was to start with 'best informed guess' properties and use trial and error to gradually expand the allowable property limits. The blend properties cited as typical fuels in an EPA presentation[18] served as the starting values for both Phases I and II. The same starting point was used for both winter and summer. Table F12, following a chart developed by the EPA[19], indicates the directional sensitivities of the properties on the standards. Of course, a more rigorous approach is possible in establishing the specification sets. For instance, one might perform incremental changes over the reformulated gasoline properties followed by computer runs to establish minimum cost specifications. However, in the event, resources were constrained. The above procedure was used after some discussion.

[18]C.L. Gray, "Reformulated Gasoline Final Rulemaking and Renewable Oxygenate Proposal," Proceedings of The World Conference on Refinery Processing and Reformulated Gasoline, March 22-24, 1994, Information Resources, Inc.

[19]Ibid.

Table F12. Directional Emission Effects of Gasoline Property Changes

Property	VOC	NO_x	Air Toxics
Rvp ↓	↓↓↓	–	↓
Sulfur ↓	↓	↓↓↓	↓↓
Aromatics ↓	↓	↓	↓↓
Olefins ↓	–	↓	–
E200 ↑	↓	↑	↓
E300 ↑	↓	–	–
Oxygen ↑	–	–	↓↓
Benzene ↓	–	–	↓↓↓

The PMM is an annual model, i.e. it does not have seasonality. A decision was made to develop, for PADDs I-IV, a single reformulated gasoline specification for Phase I simulation and a single specification for Phase II. This required several actions. The two summer sets for Phase I were linearly blended by compositing the projected gasoline sales-weighted south specifications to the appropriately weighted specifications of the north. The resulting two sets of specifications for Phase I, one for summer and one for winter, were then composited after weighting them according to summer sales and winter sales respectively.. The Phase II specifications were collapsed to a single set in the same manner. The composites were calculated in a spreadsheet maintained by the Oil and Gas Analysis Branch. This specification was adapted from the presentation made by Charles L. Gray at the conference cited above. The resulting reformulated gasoline specifications are shown in Table F13. It is, of course, a simple matter to convert the PMM blending stock distillation temperature values as needed.

Table F13. PMM Reformulated Gasoline Specifications

	Phase I PADDs I-IV	Phase II PADDs I-IV
Max Rvp, psia	8.7	8.5
Max S, ppm	305	135
Max Aro, %	25.0	25.0
Max Ole, %	12.0	12.0
Min E200, %	49.0	49.0
Min E300, %	87.0	87.0
Min Oxy, wt%	2.1	2.1
Max Ben, %	0.95	0.95

F.8 Estimation of Gasoline Market Shares

Time series market shares for traditional (TRD), oxygenated (TRH), reformulated (RFG), and reformulated/high oxygen (RFH) gasoline were estimated using a Gasoline Market Share Spreadsheet (GMSS). The estimates are based on the population of control areas (nonattainment areas requiring or assumed to require new types of gasoline) relative to the population of each Census division. Control areas used are based on a list of nonattainment areas put out by the Environmental Protection Agency [20]. Population data are from the 1990 Census, U.S. Bureau of Census.

The ratio of the control area population to the Census division population are used by PMM to disaggregate gasoline demand in that region. The control areas included in each year reflect assumptions about the phase-in of CAAA and State legislation.

MGSHR is the annual percent of total gasoline demand.

OXY ratio of population in carbon monoxide nonattainment areas, requiring oxygenated gasoline.

RFH ratio of population in areas that are both carbon monoxide and ozone nonattainment, requiring high oxygen reformulated gasoline.

[20]Environmental Protection Agency, Office of Air Quality Planning and Standards, *Ozone and Carbon Monoxide Areas Designated Nonattainment*, (October 1991, Research Triangle Park, NC).

WDEM ratio of wintertime gasoline demand to annual demand in each region (see table). The ratio was estimated using monthly gasoline sales data from the Form EIA-782A for the years 1983 through 1991.

Census Division	1	2	3	4	5	6	7	8	9
WDEM	.22	.48	.09	.06	.13	.11	.22	.30	.46

COPOP population of carbon monoxide nonattainment areas.

COOZ population of areas of overlap for carbon monoxide and severe ozone nonattainment areas.

COOZOPT population of areas in carbon monoxide and less severe ozone nonattainment areas assumed to opt-in to the reformulated gasoline program.

OZ population in nine severe ozone nonattainment areas where RFG is mandated.

OZOPT population in less severe ozone nonattainment areas assumed to opt-in to the RFG program.

DIV population of a given Census division.

SPILL "spillover demand" or demand for reformulated fuels outside the boundaries of nonattainment areas. Spillover is assumed to be 5 percent. The spillover assumption was tested between 0 and 10 percent and found to have minimal impact.

Traditional Gasoline Market Shares:

In every year the annual market share of traditional gasoline is calculated by:

$$MGSHR_{TRD,CD} = 1 - MGSHR_{TRH,CD} - MGSHR_{RFG,CD} - MGSHR_{RFH,CD}$$

where

CD represents a Census division.

Oxygenated Gasoline Market Shares:

In every year the annual market share of oxygenated gasoline is calculated as a percentage of total annual gasoline demand:

$MGSHR_{TRH,CD} = OXY_{CD} * WDEM_{CD}$

In most Census divisions the annual market share for oxygenated gasoline from **1995 forward** is calculated as follows:

$OXY_{CD} = (\sum(COPOP_{CD} - COOZ_{CD} - C00Z0PT_{CD}))/DIV_{CD} * (1 + SPILL)$

Beginning in 1996, a different estimation for oxygenated gasoline is required in **Census Division 9** due to a statewide mandate of 2.2 percent oxygen in gasoline used in California:

$OXY_{CD9} = (\sum(COPOP_{CD9} - COOZ_{CD9} - C00Z0PT_{CD9} - COPOP_{CA} - COOZ_{CA} - C00Z0PT_{CA}))/DIV_{CD9}$

Beginning in 1997, a different estimation for oxygenated gasoline is required in **Census Division 4** due to a statewide mandate of 2.7 percent oxygen in gasoline used in Minnesota:

$OXY_{CD4} = (MNPOP/DIV_{CD4)} * (1 + SPILL)$

where

MNPOP is the population of Minnesota

Reformulated Gasoline (2.0 percent oxygen) Market Shares:

The reformulated gasoline program **begins in 1995**, therefore the market share for reformulated gasoline are estimated as follows:

$MGSHR_{RFG,CD} = ((\sum(OZ_{CD} + OZOPT_{CD}))/DIV_{CD} * (1 + SPILL)) - MGSHR_{RFH,CD}$

Beginning in 1996, the reformulated market share in **Census Division 9** has a unique calculation reflecting a statewide requirement for reformulated gasoline in California:

$MGSHR_{RFG,CD9} = CAPOP/DIV_{9} + (\sum(COOZ_{CD9} + COOZOPT_{CD9} - COOZ_{CA} + COOZOPT_{CA}))/DIV_{CD9} * (1 + SPILL))$

Reformulated/High Oxygen Gasoline (2.7 percent oxygen) Market Shares:

Requirements for gasoline that is both reformulated and oxygenated occur during the wintertime in areas that fail to meet both carbon monoxide and ozone standards. **Beginning in 1995**, the market shares are estimated as:

$$MGSHR_{RFH,CD} = RFH_{CD} * WDEM_{CD}$$

where

$$RFH_{CD} = (((\sum(COOZ_{CD} + COOZOPT_{CD}))/DIV_{CD}) * (1 + SPILL))$$

Beginning in 1996, the estimation for the high oxygen/reformulated market share in **Census Division 9** must exclude sales in California because of State legislation:

$$MGSHR_{RFH,CD9} = (\sum(COOZ_{CD9} + COOZOPT_{CD9} - COOZ_{CA} - COOZOPT_{CA}))/DIV_{CD9} * (1 + SPILL))$$

F.9 Estimation of Low-Sulfur Diesel Market Shares

The CAAA90 mandates the use of low sulfur diesel for on-highway use. Market shares for low-sulfur diesel relative to distillate fuel are estimated based on data from EIA's *Annual Fuel Oil and Kerosene Sales 1992*(DOE/EIA-0535(92)). Since 20 percent of current demand in the transportation sector is off-highway, 80 percent of transportation demand for distillate fuel is assumed to be low-sulfur.

F.10 Low-Sulfur Diesel Specifications

In order to account for diesel desulfurization regulations, low-sulfur diesel is differentiated from other distillates. Specifications for sulfur, aromatics content, and API gravity are included in the PMM. Diesel fuel in Census Divisions 1 through 8 have a maximum sulfur content of 0.05 percent by weight, and a maximum aromatics content of 35 percent, reflecting Federal specifications. The specifications for diesel fuel supplied to Census Division 9 also have a maximum sulfur content of 0.05 percent but have a maximum aromatics content of 20 percent by weight, reflecting the more severe California Air Resources Board requirements.

F.11 Estimation of Regional Conversion Coefficients

Differing regional definitions necessitate the conversions of certain variables from one regional structure to another. Regional conversions are not extensive in the PMM, but are needed for three refinery input prices, refinery fuel consumption, and cogeneration information.

Conversions for Prices of Refinery Inputs

PMM receives prices for refinery inputs of natural gas in other regional configurations and must convert these into PAD District level prices. Due to the proximity of refineries in PAD Districts 2, 3, and 4 to the sources of natural gas supply, prices in these PAD Districts reflect wellhead natural gas prices in the corresponding Oil and Gas Production Regions. PAD Districts 1 and 5 use industrial prices in the corresponding Census divisions in order to capture the additional costs of moving the natural gas to the refineries. Table F14. shows the source of PAD District level natural gas prices:

Table F14. Source of PMM Natural Gas Prices

Correlation of Prices	
PAD District	Input Price
1	Census Division 2 industrial price (PGIIN)
2	Oil and Gas Production Region 3 wellhead price (OGWPRNG)
3	quantity weighted average of Oil and Gas Production Regions 2,4, & 8 wellhead price (OGWPRNG)
4	Oil and Gas Production Region 5 wellhead price (OGWPRNG)
5	Census Division 9 industrial price (PGIIN)

PMM receives prices for refinery inputs of electricity by Census division. PAD District level prices are derived by assuming prices in intersecting Census divisions. Table F15. shows the correlation between PAD District and Census division electricity input prices:

Table F15. Source of PMM Electricity Prices

Correlation of Prices	
PAD District	Input Price
1	Census Division 2 industrial prices (PELIN)
2	Census Division 3 industrial prices (PELIN)
3	Census Division 7 industrial prices (PELIN)
4	Census Division 8 industrial prices (PELIN)
5	Census Division 9 industrial prices (PELIN)

Conversions for Refinery Fuel Consumption

Refinery fuel consumption must be converted from the PAD District to the Census division level. Each Census division consumption number will equal the consumption in the overlapping PAD Districts times a factor. The factors were developed using State-level refinery operating capacity and are shown in Table F16. The factors are interpreted as follows: The 0.8434 at the intersection of Census Division 2 and PAD District I indicates that 84.3 percent of the PAD District I refinery fuel consumption is estimated (using refinery operating capacity as estimator) to occur in Census Division 2. These values will change by small amounts as refinery capacities change, but the impact on model results will be small.

Example: Census Division 7 fuel consumption =
(PAD District II consumption * .12) + (PAD District III consumption * .93)

Table F16. PAD District to Census Division Conversion Factors

	Census Division									
	1	2	3	4	5	6	7	8	9	SUM
PAD District 1		0.84			0.16					1.00
PAD District 2			0.60	0.19		0.09	0.12			1.00
PAD District 3						0.07	0.93			1.00
PAD District 4								1.00		1.00
PAD District 5									1.00	1.00

Conversions for Cogeneration

Information including cogeneration levels (RFCGGEN(CD)), cogeneration capacity (RFCGCAP(CD)), refinery fuel consumption (RFCGFUEL(CD)), self-generation (RFCGSELF(CD)), and generation for grid (RFCGGRID(CD)) must also be converted from PAD District level to Census divisions. The same factors and methodology developed for refinery fuel consumption (Table F16) are used to convert the cogeneration data.

Conversion coefficients for refinery fuel consumption and cogeneration information are estimated using &6007PRJ.PMM.CAPACITY.COEFS. An input file named &6007PRJ.PSD.CAPACITY.DATA95 contains refinery capacity data from the 1994 Petroleum Supply Annual (PSA). To update the program, operating capacity data can be pulled from IPS. (Manual updates to the data file can be made using data from Table 36 of the PSA and making some minor adjustments to the program that reads the data.)

F.12 Estimation of Sulfur Dioxide Allowance Equations

Between Oct. 1, 1993, and Dec. 31, 1999, small refineries that produce low sulfur diesel fuel will be eligible to receive allowances for sulfur dioxide emissions through the year 1999[21]. Refiners are not covered under the Acid Rain program but can trade the allowances with electric utilities and other units that must meet Title VI compliance. Allowance trading under the Acid Rain program will begin in 1995.

In order to be eligible for allowances, small refiners must desulfurize both on- and off- road diesel. A "small refinery" is defined as a refinery or portion of a refinery that has a crude throughput less than 18.25 million

[21]Proposed Rules,Federal Register, Vol. 57, No. 130, July 7, 1992, pp. 29960-29961.

barrels (MMbbl) and that is owned by a refiner with a combined throughput less than 50.19 MMbbl. The annual throughput will be measured as of November 15, 1990, according to Form EIA-810[22].

Analysis of the 1990 EIA-810 data indicates distillate production from eligible small refiners represented 12.8 percent of domestic distillate production in 1990. Identification of eligible small refiners and production of distillate was done in program CN6007.SSE.DIESEL.READ, which reads company level data from the EIA-810 data contained in CN6007.SSE.PSD.DIESEL.DATA.

AEO95 assumes that all small refiners desulfurize and produce low sulfur diesel at the national diesel (transportation and off-highway) to normal distillate ratio of 59 percent which correlates with 86,337 allowance requests. The actual number of small refiners that will choose to invest in desulfurization and the amount of the distillate yield at these refineries eligible for allowances (used as motor fuel) is very uncertain. The EPA awards allowances based on the EIA-810 which began differentiating between low sulfur and regular distillate in January 1993 but does not report end-uses. The maximum requests for allowances based on 1990 data and assuming all eligible refiners will produce only low sulfur distillate is 93,930.

Small refiner distillate volumes eligible for allowances can be estimated as:

Possible Allowance Volume (PAV) = total distillate * .128 * .59
(MMbbl)

The EPA will award allowances based on their estimates of sulfur dioxide reduction resulting from desulfurization. Each unit of low-sulfur diesel produced by eligible refiners will be equated to a .224 percent reduction in sulfur by weight[23]. Reflecting molecular weights, the reduction in sulfur is converted to a reduction in sulfur dioxide by multiplying by 2. One allowance request will be allowed for every ton of reduction in sulfur dioxide. Eligible volumes are converted to weight to estimate sulfur dioxide reduction/allowances as follows:

Possible Allowance Weight (PAW) = PAV * (302/2000 tons/bbl)
(MMtons)

and

Requested Allowances = PAW * (0.00224 % wt) * 2

Allowances for each refinery will be based on diesel yield as reported on the EIA-810.

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[22]Ibid.

[23]The percent weight .224 represents the difference in sulfur content between high-sulfur(.274 percent weight) and low-sulfur (.05 percent weight) distillates.

A maximum total of 35,000 allowances per year will be available for small refineries. An individual refinery may receive up to 1500 allowances per year. Therefore, sulfur allowances are estimated as the minimum of requested allowances estimated above or 35,000.

Future Methodology:

In January of 1993 the EIA-810 started to differentiate between low sulfur diesel and other distillate. Annual data can be used to calculate the percent of low sulfur diesel produced at small refineries. This percent should replace the 59-percent assumption discussed above.

F.13 Unfinished Oil Imports Methodology

PAD Districts I and III are the primary recipients of unfinished oil imports into the United States. Of the four categories that EIA publishes, light gas oils are practically nil and will not be modeled in PMM.

The Oil Market Module used the most recent known values for imports of unfinished oils, which remained fixed throughout the forecast period. While simplistic, this methodology was difficult to improve on.

In the methodology described below, unfinished oil imports are estimated as a function of crude oil input to refineries. Only six observations were available for this equation (1989 was an outlier and was not used), so this methodology should be reviewed later, possibly re-estimating the equation using quarterly data. Total U.S. unfinished oil imports are estimated from the equation, then the PAD District I and III values are shared out.

U.S. Unfinished Oil Imports = -2856.7 + (0.2447 * Crude Inputs)
t-stats: (-157.5) (8.97)
R-squared: .95

PAD District III Unfinished Oil Imports = U.S. Unfinished Oil Imports * 0.65
PAD District III Naphthas = PAD District III Total * 0.24
PAD District III Heavy Gas Oils = PAD District III Total * 0.27
PAD District III Residuum = PAD District III Total * 0.49

PAD District I Unfinished Oil Imports = U.S. Unfinished Oil Imports * 0.35
PAD District I Naphthas = PAD District I Total * 0.09
PAD District I Heavy Gas Oils = PAD District I Total * 0.73
PAD District I Residuum = PAD District I Total * 0.18

F.14 Product Pipeline Capacities and Tariffs

Two sources were used to obtain the product pipeline data; (1) The NPC study [24] and (2) The North American Crude Oil Distribution (NACOD) model prepared by ICF for the Office of Strategic Petroleum Reserves (OSPR) during 1990-91. The NACOD data was received in LOTUS.WK3 spreadsheet format from Don Buck of OSPR.

NACOD data for the year 2000 were used for the petroleum product pipeline capacities and tariffs (1991$). The NPC study was used for LPG and NGL pipeline capacity data. The NACOD model defines 15 crude oil demand regions (including Canada and Puerto Rico/Virgin Islands) and the NPC study uses PAD District regions. The links needed for PMM, as shown in Table F17, are based on PAD Districts for refining regions and Census divisions for demands.

Many of the arcs shown in Table F18 and Table F19 represent more than one pipeline. In some cases, we have retained more than one arc from a source to a destination in order to have a better representation of product movements.

[24]National Petroleum Council, *Petroleum Storage and Distribution, Volume 5, Petroleum Liquids Transportation*, (April 1989).

Table F17. NACOD Regions and NEMS/PMM Census Regions

NACOD Regions		NEMS/PMM Regions	
Code	Locations	Code	Locations
1	New England	1	NE, New England
2	Includes MD,DE	2	MA, excludes MD,DE
3	WV to FL	5	SA, includes MD,DE
4	KS, OK	7	WSC, includes OK,KS
5	PAD District II	3, 4	WNC,ENC, and KY, TN from 6
6	Texas Gulf Coast	7	WSC
7	LA Gulf Coast	7	WSC
8	West Texas, NM	7	WSC, excludes NM
9	AR, No. LA, No. MS, AL	6, 7	ESC,AR,LA,MS,AL
10	PAD District IV, North- ID, MT	8	MNT
11	PAD District IV, South- WY,UT,CO	8	MNT
12	Alaska		
13	Hawaii		
14	PAD District V,	9	PAC, excludes NV,AZ

The product pipeline capacities, excluding LPG/NGL service, are shown in Table F19. The matrix formulation used in PMM allows for separate arcs for product movements. For example, to deliver a barrel of gasoline to Dorsey MD (In Census Region 2) from PAD District III, (Census Region 7), requires flow on the arc from Region 7 to Region 6 (capacity of 2280 Mbbl/cd) at a cost of $0.31/bbl, flow on the arc from Region 6 to Region 5 (capacity of 2526 Mbbl/cd) at a cost of $0.74/bbl, and flow on the arc from Region 5 to Region 2 (capacity of 1392 Mbbl/cd) at a cost of $0.16/bbl. The total tariff is $1.21/bbl or 2.88 cents/gallon.

Table F18. Petroleum Product Pipeline Capacities and Tariffs[25]

Census region			
From	To	Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
ENC, 3	MA, 2	157	1.32
ENC, 3	SA, 5	20	1.40
SA, 5	MA, 2	1392	0.16
ESC, 6	SA, 5	2526	0.74
WSC, 7	ENC, 3	328	0.56
WSC, 7	WNC, 4	280	0.86
WSC, 7	WNC, 4	717	0.80
WSC, 7	ESC, 6	2280	0.31
WSC, 7	MNT, 8	81	0.74
WSC, 7	MNT, 8	58	0.73
MNT, 8	WNC, 4	44	0.99
MNT, 8	PAC, 9	73	0.99

[25]Capacities and tariffs from NACOD model.

The LPG/NGL pipelines are shown in Table F19.

Table F19. LPG/NGL Pipelines Capacities and Tariffs[26]

Census Region			
From	To	Capacity (Mbbl/cd)	Rate (Wt. avg $/bbl)
ENC, 3	MA, 2	61	2.18
WNC, 4	ENC, 3	56	0.99 (estimated)
WNC, 4	SA, 5	57	0.99 (estimated)
ESC, 6	SA, 5	109	0.65
WSC, 7	ESC, 6	120	0.28
WSC, 7	WNC, 4	225	0.65
WSC, 7	WNC, 4	65	1.14
WSC, 7	MNT, 8	47	0.84
MNT, 8	WNC, 4	12	1.15

F.15 Cogeneration Methodology

Electricity consumption in the refinery is a function of the throughput of each unit. Sources of electricity consist of refinery power generation, utility purchases, and refinery cogeneration. Power generators and cogenerators are modeled in the PMM Linear Program (LP) as separate units which are allowed to compete along with purchased electricity.

The cogeneration unit in the PMM LP was modeled using historical data as a guideline. Cogeneration activity for each refinery was aggregated to the PADD level for incorporation into the PMM LP. Cogeneration capacity, fuel consumption, and percent sales to the utility grid were estimated from the EIA-867, Annual Nonutility Power Producer Report for 1994. The data covers all of SIC 29, not just SIC 2911. Cogeneration investment and operating costs were derived from the 1980 Office of Technology Assessment (OTA) report "Industrial Cogeneration".

[26]Capacities from NPC study, tariffs from NACOD model data

Cogeneration capacity (including planned capacity) for each refining region was derived from the EIA-867 historical data base. It should be noted that the capacity provided in the data base is summertime capability and not nameplate capacity. The LP limits utilization to 90 percent of the summertime capability. Cogeneration capacity is allowed to expand when the value received from the additional product exceeds the investment and operating costs of the new unit. The value of adding capacity includes revenues from sales to the utility grid and the displacement of purchases of electricity. Investment costs are derived from the OTA report. The capacity expansion methodology is described in detail in Chapter 4.

Cogeneration fuel consumption was also calculated using the EIA-867 historical data base. It was found that consumption of 1.01 barrels of fuel oil would produce approximately 1000 kwh of electricity and 6530 lbs of steam. Since the LP refinery consumes fuel in barrels of fuel oil equivalent, shares of individual fuels were determined from the historical data and computed post process. The shares are allocated as follows:

Oil	2.10%
Natural Gas	74.15%
Other Gaseous Fuels	23.75%.

In the past, shares of all petroleum based fuels were aggregated under Petroleum Products. This category has now been divided into Oil and Other Gaseous Fuels.

In general, refineries will sell portions of the cogenerated electricity back to the utility grid. However, because of the "all or nothing" nature of an LP, sales to the grid could not be projected. If it is cost effective to sell cogeneration electricity, the LP will sell all of it. Likewise if it is not profitable, it will sell none of it. To model the situation more realistically, sales to the grid were modeled using percentages derived from the historical data base. The percentage of sales to the grid for each refining region (PADD) was calculated from the 1994 data as follows:

REGION	PERCENT SOLD TO GRID
PADD 1	63.24
PADD 2	0.87
PADD 3	5.09
PADD 4	80.78
PADD 5	46.29

The LP is forced to sell electricity back to the grid in these percentages at a price equal to the average price of electricity.

Fixed operating costs are calculated in the model as a function of cogeneration capacity while variable operating costs are determined as a function of electricity generated. The following rates were determined from the OTA report.

Annual Fixed Cost $7.32/kw
Variable Cost $0.00565/kwh

Data from the EIA-867 report was reconfigured using the following SAS program to extract information necessary to the LP.

CN6007.JDI.COGEN.HISTRY94.DATA manipulates the EIA-867 raw data so that all pertinent information for each refinery is contained in one line (SAS observation). The EIA-867 refinery data is aggregated by PADD and census division (CD) for input into the PMM history file. The PMM LP requires data to be sorted by PADD whereas the NEMS model requires cogeneration data be aggregated by CD. The program also calculates fuel allocation shares, and percentage of sales to the utility grid. The results are stored in the SAS database **CN6007.JDI.COGEN.F867.DATA94.SASDB.**

F.16 Natural Gas Plant Fuel Consumption

The consumption of natural gas by natural gas processing plants is modeled as a function of dry gas production. Natural gas consumed at gas processing plants is calculated as a percentage of dry gas production using data from the *Natural Gas Annual 1992*. The ratios are calculated by PAD District, except for PAD District V where Alaska is computed separately from the rest of PAD District V.

PAD District I	1.36
PAD District II	2.50
PAD District III	2.43
PAD District IV	2.61
PAD District V	2.25
ALASKA	8.93

F.17 Alaskan Crude Oil Exports

In November 1995, the ban on exports of Alaskan North Slope (ANS) oil was lifted. Exports began in the spring of 1996.

The theory supporting the economic incentives for exporting Alaskan crude is as follows. The current restriction on ANS crude probably results in an undervaluing of ANS crude on the West Coast. The value of ANS crude on the West Coast would be expected to rise with greater amounts of ANS crude exports. In the Pacific refining regions, the value of ANS crude would decline as larger quantities flowed into the region. At some point, the rising value on the West Coast and the declining value in the Pacific regions would come together and the economic incentive to export ANS would cease.

The PMM does not have refinery representation for foreign regions, but instead relies upon supply curves to represent import availability of both crude oil and petroleum products. Allowing crude exports from Alaska could not be done, therefore, simply by adding a transportation vector from Alaska to the Pacific refining region. Instead, three vectors were added with specified quantities and target prices which represent the value of exporting ANS crude to the Pacific region. If the target price associated with the vector was higher than the value of ANS crude oil in PADD V, then the exports would flow. Since the value of ANS crude in the Pacific region is expected to fall as export flow increases,[27] the target prices declined across the three vectors.

[27] Table 3.1, page 45, U.S. Department of Energy, *Exporting Alaskan North Slope Crude Oil*, DOE/PO-0025 (Washington, D.C., June 1994)

APPENDIX G

Matrix Generator Documentation

APPENDIX G. Matrix Generator Documentation

G.1 Introduction

The purpose of this report is to describe the program which runs the Multi-Refining Model (MRM) (5-regions) and the Enhanced Refinery Model (ERM) (single region); and to provide detail on how it works. The program allows the user to simulate a single region (ERM) or a 5-region (MRM) representation of the entire refining industry in the United States.

The ERM model simulates a single PADD (Petroleum Administration for Defense District) and has no transportation of crude oil to the refinery region nor product from the refinery region. Instead, crude oil is supplied directly to the refinery gate and product demands are satisfied at the refinery gate. The ERM projects petroleum product prices, product demands, crude oils, alcohols, ethers, natural gas and fuel consumption; and capacity expansion in a PADD.

The 5-region MRM simulates multiple PADD regions. It is a collection of ERMs linked by a transportation network. It simulates the entire refining industry in the United States. The MRM simulates the operation of petroleum refineries in the United States, 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 product to meet regional demands. In addition to the quantities that an ERM produces, the MRM identifies sources of supply for domestic and imported crude oils, alcohols, ethers and natural gas. The 5-region MRM simulates five PADD's (I, II, III, IV, and V whose letter codes are E, C, G, M, and W).

The program generates the matrix for the linear programming model representation of the ERM or MRM, solves it, writes the solution, reports, and packs the matrix for use by the analyst using the ANALYZE software.

G.2 Code

The program is written in Fortran and makes use of the OML (Optimization and Modeling Libraries) to read in the data files, generate the matrix representation of the model, solve the problem, store the solution, and pack the matrix for use with ANALYZE. In addition to the above, the program produces reports.

The program is data driven and the user provides key information such as the model he chooses to run, the location of the input data files, and some other options.

G.2.a Variables and Constraints

The model consists of variables or activities (columns), constraints (rows), and bounds on activities. A unique name has been assigned to each variable and constraint. In the naming of the variables and rows, indices were used. The following table displays the index set name and the number of elements in the set and gives a brief description of the set and a partial listing of the set members.

Index	No. of Values	Description	Members
@	1	represents all regions	@
c	2	Constraint type	X: for max N: for min
d	9	Census divisions	1: New England 2: Mid Atlantic 3: East North Central 4: West North Central 5: South Atlantic 6: Est South Central 7: West South Central 8: Mountain 9: Pacific
e	2	Emission source	C: Emission from fuel combustion N: Emission from process unit
m	15	Transportation mode, function of material and means of movement	4: U.S. flag residual oil 5: South Atlantic node 6: East South Central node A: Crude pipeline from G to C B: Barge residual oil I: West Texas to PADD 2 J: U.S. flag light products O: U.S. flag LPG R: PADD 3 loop to PADD 2 S: PADD 3 capeline to PADD 2 T: Light product pipeline U: LPG, C4, CC5 pipeline V: Barge residual oil X: Local transportation Y: Pipeline PADD C to region 6 Z: Psudo link

Index	No. of Values	Description	Members
o	8	OGSM regions	0: OGSM 1A East Coast 1: OGSM 1B East West part 2: OGSM 2 Gulf Coast 3: OGSM 3 Midcontinent 4: OGSM 4 Permian Basin 5: OGSM 5 Rocky Mountain 6: OGSM 6 West Coast A: OGSM A Alaska North
r	5	Refining regions	E: PADD I C: PADD II G: PADD III M: PADD IV W: PADD V
t	2	Type of transportation	V: Vessel P: Pipeline
x	5	Exporting regions	2: Export cd for PADD I 3: Export cd for PADD II 7: Export cd for PADD III 8: Export cd for PADD IV 9: Export cd for PADD V
Nn	3	Negative shift in demand	N1, N2, N3
On	8	Natural Gas refinery supply steps	N1, N2, N3, N4, P5, P6, P7, P8
Pn	3	Positive shift in demand	P1, P2, P3
qm	11	Quality code for gasoline blending	AR: Aromatics BZ: Benzene E2: E 200 E3: E 300 MO: Motor octane PO: Percent oxygen OL: Olefine RO: Research octane RV: Reid vapor pressure SL: Sulfur RE: renewables component (due to required minimum contribution to oxygenates)
qd	7	Quality code for distillate	AR: Aromatics FL: Flash point FZ: Freezing point GR: Gravity LM: Luminometer number SL: Sulfur VB: Viscosity

Index	No. of Values	Description	Members
Qs	3	Step label for crude oil imports	Q1, Q2, Q3
Rs	9	Step label for product imports	R1, ..., R9,
S1	1	Step label for product demands	S1
SX	1	Product exports	SX
Z9	1	Distress imports and exports	Z9
crt	12	Crude groups by quality and origin	ALL: Alaskan, API 25-66, S<0.5, B<15 AMH: Alaskan, API 21-32, S<1.1, B>15 DLL: Domestic, API 25-66, S<0.5, B<15 DMH: Domestic, API 21-32, S<1.1, B>15 DHL: Domestic, API 29-56, S<1.99, B<15 DHH: Domestic, API 23-35, S<3.0, B>15 DHV: Domestic, API<23, S>0.7, B>15 FLL: Foreign, API 25-66, S<0.5, B<15 FMH: Foreign, API 21-32, S<1.1, B>15 FHL: Foreign API 29-56, S<1.99, B<15 FHH: Foreign, API 23-35, S<3.0, B>15 FHV: Foreign, API<23, S>0.7, B>15
dfo	5	Distillate fuel oil blends	JTA: Jet fuel N2H: Number 2 oil DSL: Low sulfur diesel N6I: Low sulfur resid N6B: High sulfur resid
emu	6	Emission type	CAR: Total carbon CO1: Carbon monoxide CO2: Carbon dioxide NOX: Nitrous oxides SOX: Sulfur oxides VOC: Volatile organic compounds
ist	1037	Refinery intermediate streams	LNI: Light naphtha, (175-250) intermediate LNN: Light naphtha, (175-250) naphthenic LNP: Light naphtha, (175-250) paraffinic
mgb	2	Gasoline blends	TRG: Traditional gasoline RFG: Reformulated gasoline
mod	many	Operating mode	C2A: Ethyl alkylate C3A: Propyl alkylate C4A: Butyl alkylate

Index	No. of Values	Description	Members
ncr	10	Non crude purchase	ARB: Atmospheric resid of type B CC3: Propane ETH: Ethanol HGM: Heavy gas oil medium sulfur IC4: Isobutane MET: Methanol MTB: M.T.B.E. NAT: Natural gasoline NC4: Normal butane NPP: Paraffinic naphtha
pol	25	Policy type	LOS: Lost OVC: Other variable cost MSD: Maximum distillation feed, cat cracker MSR: Maximum low sulfur resid, cat cracker SVR: Maximum severity, cat cracker H00: Maximum 100 severity, HP reformer H05: Maximum 105 severity, HP reformer
prd	18	Products	AST: Asphalt COK: Coke DSL: Low sulfur diesel E85: 85% Ethanol and 15% TRG JTA: Jet fuel LPG: Liquefied petroleum gas M85: 85% Methanol and 15% TRG N2H: Number 2 oil N67: Low sulfur resid to utilities N68: High sulfur resid to utilities N6B: High sulfur resid N6I: Low sulfur resid OTH: Other PCF: Petrochemical feed stock RFG: Reformulated gasoline RFH: Reformulated high oxygen gasoline TRG: Traditional gasoline TRH: Traditional high oxygen gasoline
pri	12	Product imports	DSL, JTA, LPG, MET, MTB, N2H, N6B, N6I, OTH, PCF, RFG, TRG
prx	10	Product exports	COK, DSL, JTA, LPG, N2H, N6B, N6I, OTH, PCF, TRG
px9	16	Distress exports	AST, COK, DSL, JTA, LPG, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH
pi9	18	Distress imports	AST, COK, DSL, E85, JTA, LPG, M85, N2H, N67, N68, N6B, N6I, OTH, PCF, RFG, RFH, TRG, TRH

Index	No. of Values	Description	Members
unf	3	Unfinished oil	ARB: Atmospheric residual bottom type B HGM: Heavy gas oil medium sulfur NPP: Medium naphtha paraffin
uns	60 (mrm) 56 (erm)	Process unit (excludes merchant & gas plant in ERM)	ACU: Atmospheric crude distillation See Appendix A for complete list of processes
uuu	3	Utility	KWH: Kilo-watt hour NGF: Natural gas liquids STM: Steam

In the naming of the columns and rows, the limit is a maximum of eight characters per name. The following two tables give the name of the variable (activity) and the row (constraint) represented.

The general name structure for columns is (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

MRM	ERM	Name	Activity Represented
x	x	B(r)(mgb)(ist)	Blend stream (ist) to gasoline grade (mgb) in (r)
x		C(d)ETHR(s)	Ethanol supply step (s) in (d)
x	x	D(d)(prd)S1	Product (prd) demand in (d)
x		D(d)(prx)SX	Product (prx) exports from (d)
x		D(d)(px9)Z9	Distress product (px9) export from (d)
x	x	E(r)(uns)INV	Investment in new capacity for process (uns) in (r)
x	x	F(r)(dfo)(ist)	Blend stream (ist) to distillate fuel oil (dfo) in (r)
x		G(r)DGR	Dry gas residue in (r)
x		G(r)GPL01	Gas plant operations mode 01 in (r)
x		G(r)(ist)(prd)	Gas plant output transfer of stream (ist) to product (prd) in (r)
x		G(r)MOH01	Methanol plant operations in (r)
x		G(r)(ist)RFN	Transfer of gas plant stream (ist) to refinery in (r)
x		G(r)METDEM	Methanol production from methanol plant in (r)
x		G(r)SC2CC1	Shift of ethane to natural gas in gas plant in (r)
x		G(r)SC3CC1	Shift of propane to natural gas in gas plant in (r)
x		H(r)(uns)(mod)	Production of mode (mod) for process (uns) at merchant plant in (r)
x		H(r)(aa)(bb)(ist)*	Transfer from (aa) to (bb) of stream (ist) in (r)
x		I(d)(pi9)Z9	Distress product (pi9) imports to (d)
x		I(r)(pri)R(s)	Imported product (pri) step (s) to region (r)
x	x	K(r)(uns)CAP	Existing capacity for process (uns) in (r)
x	x	L(r)(uns)BLD	Addition to capacity for process (uns) in (r)
	x	N(r)(ncr)	Purchase noncrude and additives (ncr) in (r)
x		N(r)DGP	Dry gas supply in (r)
x		N(r)NGRF(On)	Natural gas to refinery supply step (On) in (r)
x		NZAMH(On)	Export supply step (on) for Alaskan crude
x		O@CRDEXP	Alaskan crude exports

MRM	ERM	Name	Activity Represented
x		O@CRDSPR	SPR fill in US
x		P(o)DCRQ1	Domestic crude in (o)
	x	P(r)(crt)	Supply of crude (crt) to (r)
x		P(r)(crt)(Qs)	Supply step (Qs) of imported crude (crt) to (r)
x		PANGLQ1	Supply of natural gas liquids from Alaska North slope
x	x	Q(r)(mgb)	Spec vector, total volume for (mgb) in (r)
x	x	Q(r)(dfo)	Spec vector, total volume for (dfo) in (r)
x	x	R(r)ACU(crt)	Volume of crude (crt) processed by the ACU unit in (r)
x	x	R(r)(uns)(mod)	Refinery process (uns) operation for mode (mod) in (r)
x	x	T(r)(ist)(ist)	transfer of stream (ist) to stream (ist) in (r)
x		T@UNFTOT	Total unfinished oils in US
x		TAAMHXZ	Volume of AMH crude transported from Alaska to Valdez
x	x	T(r)CBNTAX	Carbon tax in (r)
x	x	U(r)(uuu)	Utility (uuu) purchased in (r)
x		VTVC(m)CP	Crude vessel transportation capacity for mode (m)
x		VTVP(m)CP	Product vessel transportation capacity for mode (m)
x		VTPC(r)*(m)(d)	Crude pipeline transportation capacity from (r) to (d) using mode (m)
x		VTPP(r)*(m)(d)	Product pipeline transportation capacity from (r) to (d) using mode (m)
x		VTPL(r)*(m)(d)	LPG pipeline transportation capacity from (r) to (d) using mode (m)
x		W(r)(prd)(m)(d)	Product (prd) transportation from (r) to (d) using mode (m)
x		W(d)(prd)(m)(r)	Product (prd) transportation from (d) to (r) using mode (m)
x		X(d)(prd)SPG	Recipe blends of product (prd) for oxygenated fuels and electric utility residual oils in (d)
x	x	X(r)(ist)(prd)	Recipe blends of product (prd) from stream (ist) in region (r)
x		X(d)(ist)(prd)	Splash blending of (prd) from stream (ist) in (d)
x		X(r)(yyyy)**	Recipe blends (yyyy) in region (r)
x		Y(o)(crt)(m)(r)	Crude (crt) transportation from (o) to (r) using mode (m)
x		Y(r)(crt)(m)(r)	Crude (crt) transportation from (r) to (r) using mode (m)

* : (aa), (bb) = MP, GP, RF, where MP = Merchant plant, GP = Gas plant, RF = Refinery. For (ist), first and last character of (ist).

**: (yyyy) = recipe blends for categories of products such as AST, PCF, OTH.

The general name structure for rows is: (v)(r)(abc)(def), where v is key code, r is region code, abc and def are 3 character names.

MRM	ERM	Name	Constraint Represented
x		A(d)(prd)	Product demand accounting row in (d) for (prd)
x		A(d)GO8(xx)	Gasoline blending accounting row in (d) for (xx)
x		A(d)RFG(xx)	Gasoline blending accounting row in (d) for (xx)
x		A(d)TRGTRH	Gasoline blending accounting row in (d)
x		A(x)PRDEXP	Product export accounting row in (x)
x		A(d)ETHTAX	Ethanol tax accounting row in (d)
x	x	A(r)NGLPRD A@NGLPRD	NGL accounting in (r); US total
x	x	A(r)INVST	Investment accounting row in (r)
x	x	A(r)(prd)	Product (prd) refined accounting row in (r)
x	x	A(r)CRX(crt)	Crude oil (crt) accounting row in (r)
x		A@CRDAKA	Alaskan crude oil accounting row in US
x		A@CRDDCR	Domestic crude oil accounting row in US
x		A@CRDEXP	Crude oil export accounting row in US
x	x	A@CRDFCR	Foreign crude oil accounting row in US
x		A@CRDL48	Lower 48 crude oil accounting row in US
x		A@CRDSPR	SPR crude oil accounting row in US
x	x	A@CRDTOT	Total crude oil accounting row in US
x		A(r)ETHRFN	Ethanol to refinery accounting row in (r)
x	x	A(r)FUEL	Fuel use accounting row in (r)
x	x	A(r)FUM(xx)	FUM accounting row in (r) for (xx)
x	x	A(r)FXOC	Fixed cost accounting row in (r)
x		A(d)G(I)(yyy)	Gasoline blend components accounting row in (d) for (yyy)
x	x	A(r)G(I)(xxx) A@G(I)(xxx)	Gasoline blend components accounting row in (r) for (xxx); US total
x	x	A(r)GAIN	Gain accounting row in (r)
x	x	A@KWHRFN	Refinery KWH usage accounting row in US
x		A(r)METIMP A@METIMP	Methanol imports accounting row in (r); US total

MRM	ERM	Name	Constraint Represented
x		A@METDEM	Methanol demand accounting row in US
x		A@METM85	Accounting of methanol used for M85 splash blending in US
x		A@METPRD	Methanol production accounting row in US
x	x	A(r)METRFN	Accounting of methanol consumption by ETH refinery unit in (r)
x		A(r)MTBRFN	MTB refinery imorts accounting row in (r)
x	x	A(r)NGFTOT A@NGFTOT	Natural gas purchase accounting row in (r); US total
x		A(r)NGLRFN A@NGLRFN	Accounting of NGL transfer from gas plant to refinery in (r); US total
x	x	A(r)NGSH2P A@NGSH2P	Accounting of NGS consumption by H2P refinery unit in (r); US total
x		A(r)NGSMER A@NGSMER	Accounting of methanol transfer from gas plant to refinery in (r); US total
x		A(r)NGSMET A@NGSMET	Methanol lant production accounting row in (r); US total
x	x	A(r)NGSRFN	Accounting of NGF stream transfer to NGS stream in (r)
x	x	A@PETCOK	Accounting of high & low sulfur coke production from recipe blending in US
x	x	A@SULSAL	Accounting of sulfur production from recipe blending in US
x	x	B(r)(ist)	Balance for intermediate stream (ist) in (r)
x		C(o)(crt)	Crude balance for crude type (crt) in (o)
x	x	C(r)(crt)	Crude balance for crude type (crt) in (r)
x	x	D(d)(prd)	Final demand for product (prd) in (d)
x		E(r)(emu)(e)	Emission of (emu) from source (e) in (r)
x		F(r)UNF(unf)	Unfinished oil balance for (unf) in (r)
x	x	F@TOTCRD	Total crude balance for unfinished oil constraint in US
x		G(r)(ist)	Gas plant balance for stream (ist) in (r)
x		G(r)(pol)	Gas plant policy (pol) accounting row in (r)
x		H(r)(ist)	Merchant oxygenate plant balance row for (ist) in (r)
x		H(r)FUMCAP	Merchant oxygenate fuel balance row in (r)
x		H(r)(pol)	Merchant oxygenate plant policy (pol) accounting row in (r)
x	x	L(r)(uns)CAP	Process (uns) capacity in (r)
x	x	M(r)(prd)	Final product (prd) demand at refinery (r)

MRM	ERM	Name	Constraint Represented
x		O(o)(crt)	Domestic crude oil (crt) accounting in (o)
x	x	OBJ	Objective function
x	x	P(r)(pol)	Policy (pol) constraint in (r)
x	x	P(r)CBNTAX	Carbon tax accounting row in (r)
x	x	Q(r)(prd)(qd)(c) Q(r)(prd)(qm)(c)	Product (prd) specification for quality (qd) constraint type (c) in (r) Product (prd) specification for quality (qm) constraint type (c) in (r)
x	x	S(r)(mgb)E	Sum row for blending gasolines (mgb) in (r)
x	x	S(r)(dfo)E	Sum row for blending fuel oils (dfo) in (r)
x	x	S(r)RFGOXY	Constraint on renewable OXY limits in (r)
x		T(t)C(m)CP	Crude oil transportation (t) capacity limits for mode (m)
x		T(t)P(m)CP	Product transportation (t) capacity limits for mode (m)
x		TPC(r)(m)(d)	Crude transportation capacity balance row
x		TPL(r)(m)(d)	LPG transportation capacity balance row
x		TPP(r)(m)(d)	Product transportation capacity balance row
x	x	U(r)(uuu)	Utilities (uuu) in region r
x	x	Z(r)CAP(uns)	Balance row for total capacity of (uns) in (r)
x		Z(r)NGFSUM	Sum row for natural gas to refineries in (r)
x		ZZAMHSUM	Sum row for Alaskan crude export
x	x	Z@WOP	Current world oil price in value of RHS
x	x	Z@CRDTOT	Sum row for total crude in US
x	x	Z@YRITER	Iteration year
x		Z@IRACX	Sum row to force average refinery crude cost within specified range
x		Z@IRACN	Sum row to force average refinery crude cost within specified range
x	x	ZD(mmddyy)	Month, day, year of matrix generation

(I) = 01, 02, ... , 12
(xx) = LPG, N2H, N6B, N6I, NGS, OTH, STG
(xxx) = TRG and RFG
(yyy) = TRG, RFG, TRH, RFH
There are several other accounting rows.

The following Table gives the dimensions of each model:

Model	Columns		Rows	
	Total	Fixed	Total	Fixed
MRM (5 regions)	13131	410	5181	4026
ERM (single region)	2274	38	914	709

The general structure for the model is as follow:

MRM Model Block Diagram

	Crude Trans.	Purchases Crude Oil, Other Inputs	Crude Distillation	Other Process Unit Operations	Capacity Expansion	Stream Transfers	Blending	Product Demand	Product Trans.	Row Type	RHS
Objective	-ct	-c	-o	-o	-i			+p	-pt	NC	Max
Crude Oil Balance	+1 +1	+1 +1	-1 -1							EQ	0
Intermediate Stream Balance			+y +y	-1 -1 +y +y		-1 +1 -1 +1	-1 -1			EQ	0
Utilities		+1	-u	-u +1						EQ	0
Policy Constraints				+z -z				+z -z		GE LE	0
Environmental Constraints			+q	+q						GE LE	E
Unit Capacities			+1	+1	-1					LE	K
Quality Specifications							+q +q -Q			GE LE	0
Product Sales							-1	-1	-1 +1 +1 -1	EQ	0
Pipeline/Marine Capacities	+1 +1								+1 +1	LE	C
Bounds	Up/Lo/Fix	Up/Lo/Fix						Lo/Fix			

Legend:
c = crude cost
p = price
Q = product specifications
y = yield
z = policy ratio
C = pipeline/marine capacity
u = utility consumption
q = stream quality
K = unit capacity
ct = crude transportation cost
E = environmental quality limit
o = operating cost
pt = product transportation cost
i = investment cost

G.2.b Subroutines

The program consists of several subroutines and a main program. The subroutines can be grouped as those that setup the OML environment, read in the data tables, form parts of the matrix representation of the model, solve the model, retrieve needed information for report writing, and write the reports. All the subroutines that generate part of the matrix representation of the model use input from data files in an OML format. These files have a .dat extension. Some subroutines use ASCII files as input and some others don't use any. The following table shows the subroutine names, the input data file names, the purpose of the subroutines, and the model that uses them.

Subroutine	Data file	Purpose	Models
accunit.f	accunit.dat	Represents ACU unit	All
akaexp.f	akaexp.dat	Represents Alaskan exports	MRM
avoids.f	avoids.dat	Represents the avoids	MRM
cogener.f	cogener.dat cogenere.dat	Represents the cogeneration	MRM ERM
crdimprt.f	crdimprt.dat	Represents crude imports	MRM
demand.f	demand.dat	Represents demands	MRM
distblnd.f	distblnd.dat	Represents distillate blending	All
distress.f	distress.dat	Represents the distress imports and exports	MRM
domcrude.f	domcrude.dat	Represents crude inputs	MRM
emish.f	emish.dat	Represents emissions	MRM
ermcrude.f	ermcrude.dat	Represents crude inputs	ERM
ermother.f	ermother.dat	Represents non-crude inputs	ERM
ermprod.f	ermprod.dat	Represents product demands	ERM
ethanol.f	ethanol.dat	Represents ethanol supply and prices	MRM
fixcol.f	fixcol.dat	Fixes some columns	All
fuelmix.f	fuelmix.dat	Simulates fuel mixing	All
gasoblnd.f	gasoblnd.dat	Simulates gasoline blending	All
limpol.f	limpol.dat	Puts limits on policy rows	All
lplookup.f		Retrieves solution	MRM
main.f	mrmparam, mrmpath main.dat ermparam pathe maine.dat	Sets up the OML environment, reads in some main data, controls the program, calls subroutines to form matrix, solves problem, stores solution, writes reports, basis and packs matrix.	MRM ERM

Subroutine	Data file	Purpose	Models
mchproc.f	mchproc.dat	Simulates the merchant plant	MRM
ngprod.f	ngprod.dat	Provides gas supply steps to refinery	MRM
nrfplant.f	nrfplant.dat	Simulates the non refinery plant activities	MRM
output.f		Prints a report	MRM
prdexp.f	prdexp.dat	Simulates the product exports	MRM
prdimprt.f	prdimprt.dat	Simulates the product imports	MRM
recipes.f	recipes.dat	Specifies product recipe blends	All
refproc.f	refproc.dat	Simulates the refinery	All
setrows.f	setrows.dat	Sets some rows	All
splash.f	splash.dat	Simulates splash blending	MRM
stream.f	stream.dat	Simulates stream transfers	All
tabread.f		Reads data tables	All
transit5.f	transit.dat	Simulates the product and crude oil transportation for the 5-region representation of MRM	MRM
unfinished.f	unfinish.dat	Provide for unfinished oil imports	MRM
utility.f	utility.dat	Simulates utility purchased	MRM
utilitye.f	utilitye.dat	Simulates utility purchased	ERM

Most of the subroutines that constitute the program generate part of the matrix representation of the model. In the following we will give a representation of the submatrix generated by each subroutine in table form. Columns of the tables correspond to activities (variables), and rows of the tables to constraints. The symbols x, -x or +-x represent matrix coefficient.

accunit.f: This subroutine simulates the ACU unit. It creates the following submatrix:

	R(r)ACU(crt)
C(r)(crt)	-x
L(r)ACUCAP	x
A(r)CRDFCR*	x
A@CRDFCR*	x
A(r)CRX(crt)	x
A@CRDTOT	x
Z@CRDTOT*	x
F@TOTCRD	x

	R(r)ACU(crt)
B(r)(ist)	+-x
U(r)(uuu)	-x
P(r)(pol)**	+-x

* for (crt) = FLL, FMH, FHL, FHH, and FHV
** for (pol) = OVC, FRL

Bounds: None

akaexp.f: This subroutine simulates the Alaskan exports. It creates the following submatrix:

	NZAMH(i)	ZZAMHTOT	TAAMHXZ	PANGLQ1
OBJ	+-x*	x	-x	-x
CAAMH			-x	
CZAMH		-x	x	
BW(ist)				x
ZZAMHSUM	x	-x		
A@AKAEXP		x		
A@CRDEXP		x		
AANGLPRD				x
A@NGLPRD				x
AWNGLRFN				x

(i) = N1, N2, N3, P4, P5, P6
* : -x if i = N1, N2, N3; x if i = P4, P5, P6

Bounds: PANGLQ1, NZAMH(i)

avoids.f: This subroutine simulates the avoids. It is turned off. It creates the following submatrix:

	D(d)(prd)N(i)	D(d)(prd)P(i)
D(d)(prd)	x	-x
OBJ	-x	-x
A(d)(prd)	-x	x
A@PRDDEM	-x	x
A@AVDNEG	x	

	D(d)(prd)N(i)	D(d)(prd)P(i)
A@AVDPOS		x

(i) = 1, ..., 3

Bounds: D(d)(prd)N(i) and D(d)(prd)P(i)

cogener.f: This subroutine simulates the cogeneration unit. It creates the following submatrix

	E(r)CGNINV	K(r)CGNCAP	L(r)CGNBLD	R(r)CGNCGN	U(r)(uuu)*
B(r)FUL				-x	
L(r)CGNCAP	-x	-x	-x	x	
OBJ	-x		-x	x	-x
P(r)OVC				-x	
U(r)(uuu)				x	
A@FXOC	x		x		
A(r)FXOC	x		x		
A@INVST	x				
A(r)INVST	x				
A@KWHRFN				x	

crdimprt.f: This subroutine simulates the crude imports into the United States. It creates the following matrix:

	P(r)(crt)(Qs)
C(r)(crt)	x
OBJ	-x
Z@IRACN	x
Z@IRACX	x

(Qs) = supply step Q1,Q2,Q3

Bounds: P(r)(crt)Q(s)

demand.f: This subroutine simulates product demands. It creates the following submatrix:

	D(d)(prd)S1	D@METS1
D(d)(prd)	-x	
OBJ	x	
A(d)(prd)*	x	
A@METDEM		x
A@PRDDEM	x	
D@MET		-x

* for (prd) not equal to E85 or M85

Bounds: D@METS1 and D(r)(prd)S1

distblnd.f: This subroutine simulates the distillate blending. It creates the following matrix:

	F(r)(dfo)(ist)	Q(r)(prd)*
B(r)(ist)	+-x	
M(r)(prd)*		x
Q(r)(prd)*(qq)(c)	+-x	-x
S(r)(dfo)E	x	-x
U(r)STM		-x
A(r)(prd)*		x
A@PRDRFN		x

* for (prd) = (dfo) only

Bounds: None

distress.f: This subroutine simulates product distresses. It creates the following submatrix:

	I(d)(pi9)Z9	D(d)(px9)Z9
OBJ	-x	-x
D(d)(pi9)	x	
A@ZZIMP	x	
D(d)(px9)		x
A@ZZEXP		x

Bounds: None

domcrude.f: This subroutine simulates domestic crudes. It creates the following submatrix:

	P(o)DCRQ1	PADCRQ1	O@CRDEXP	O@CRDSPR
OBJ	-x	-x		
C(o)(crt)	x	x		
CAAMH			-x	
CGFHL				-x
A@CRDDCR	x	x		
A@CRDAKA		x		
A@CRDL48	x			
A@CRDEXP			x	
A@CRDSPR				x
A@CRDFCR				x
Z@IRACN	x			
Z@IRACX	x			
O(o)(crt)	x			

(o) : except A

Bounds: P(o)DCRQ1, PADCRQ1, O@CRDEXP, O@CRDSPR

emish.f: This subroutine simulates emissions. It creates the following submatrix:

	K(r)(uns)CAP	R(r)FUM(ist)
E(r)(emu)N	x	
E(r)(emu)C		x

Bounds: None

ermcrude.f: This subroutine simulates domestic crudes for ERM. It creates the following submatrix:

	P(r)(crt)*
C(r)(crt)*	x
OBJ	-x

* (crt) = FHH, FHL, FHV, FLL, FMH, DLL, DMH, DHL, DHH, DHV.
(r) = PADD G only

Bounds: P(r)(crt)

ermother.f: This subroutine simulates the non-crude inputs for ERM. It creates the following submatrix:

	N(r)(ist)*
B(r)(ist)*	x
OBJ	-x
A(r)(ist)*	x

* (ist) = (ncr) only
(r) = PADD G only

Bounds: N(r)(ist)

ermprod.f: This subroutine simulates product demands for ERM. It creates the following submatrix:

	D(r)(prd)S1
M(r)(prd)	-x
OBJ	x

(r) = PADD G only

Bounds: D(r)(prd)S1

ethanol.f: This subroutine represents ethanol supply and prices. It creates the following submatrix:

	C(d)ETHR(i)	Z(d)ETHTAX	X(d)ETHE85
D(d)ETH	x		
OBJ	-x	x	-x
A(d)ETH	x		
A(d)ETHTAX	x	-x	
A@ETHPRD	x		

i = 1, ..., 4

Bounds: C(d)ETHR(i)

fixcols.f: This subroutine fixes some variables or activity. No submatrix is generated

Bounds: R(r)FCC(ist)

fuelmix.f: This subroutine simulates fuel mixing. It creates the following submatrix:

	R(r)FUM(mod)	T(r)CBNTAX	K(r)FUMCAP
OBJ		-x	
P(r)CBNTAX		x	
A(r)FUM(mod)	x		
A@FUM(mod)	x		
A(r)FUEL			x
A@FUEL			x

Bounds: None

gasoblnd.f: This subroutine simulates gasoline blending. It creates the following submatrix:

	B(r)(mgb)(ist)	Q(r)(mgb)	Z(r)RFGOXY
B(r)(ist)	-x		
M(r)(prd)		x	
Q(r)RFGREN	x		-x
Q(r)(prd)(qq)(c)	x	-x	
S(r)(mgb)E		-x	
S(r)RFGOXY			-x
U(r)KWH		-x	
A(r)(xxx)(mgb)	x		
A(r)(prd)*		x	
A@(xxx)(mgb)	x		
A@PRDRFN		x	

* (prd) = (mgb) only; (xxx) = GO1, ..., G12

Bounds: None

limpol.f: This subroutine defines policy conditions. It creates the following submatrix:

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	Z(r)FLO(uns)
Z(r)CAP(uns)	x	x	x	-x
P(r)(pol)				-x

(uns) = specific units underpolicy controls (i.e., FCC, KRF,...)

Bounds: None

lplookup.f: Retrieves solution values and stores them in arrays.

main.f: This subroutine reads in the mrmparam file that has the information relative to the model to run; initializes the OML subroutine library environment; opens the database; specifies a problem in the database for processing; initializes the matrix processing; reads in the path file, the main.dat file that contains some global variables such as the refinery, the exporting, and demand regions code; calls the subroutines that generate the matrix; ends the matrix processing; writes out the MPS file; inserts the advanced basis; solves the matrix; puts the solution in output; writes the optimal basis; prints reports; packs the matrix; and closes the database.

mchproc.f: This subroutine represents the merchant plant. It creates the following submatrix

	K(r)(uns)CAP	E(r)(uns)INV	L(r)(uns)BLD	K(r)FUXCAP	H(r)(uns)(mod)
H(r)FUMCAP				x	x
L(r)(uns)CAP	-x	-x	-x		x
OBJ		-x	-x		
A@FXOC		x	x		
A(r)FXOC		x	x		
A@INVST		x			
A(r)INVST		x			

mchproc.f (Continued)

	H(r)(uns)(mod)	H(r)KWHMCH	H(r)(aa)(bb)(ist)*	T(r)MCHOVC
H(r)(ist)	+-x		+-x	
H(r)(uuu)	+-x			
H(r)(pol)	+-x			
G(r)(ist)			+-x	
B(r)(ist)			+-x	
H(r)KWH		x		
H(r)OVC				x
OBJ		-x	-x	-x

*: first and last character of (ist); (aa) and (bb) = MP, GP, RF
where MP = Merchant plant, GP = Gas plant, and RF = Refinery

Bounds: K(r)(uns)(CAP, E(r)(uns)INV, L(r)(uns)BLD, H(r)GPMP(ist) and H(r)RFMP(ist) = 0

ngprod.f: This subroutine represents the gas supply steps to refinery. It creates the following submatrix

	N(r)NGRF(ij)*
OBJ	+-x**
Z(r)NGFSUM	x

* (ij) = N1, N2, N3, N4, P5, P6, P7, P8
** +x for N1, N2, N3, N4 and -x for P5, P6, P7, P8

Bounds: N(r)NGRF(ij)

nrfplant.f: This subroutine simulates the non refinery plant. It creates the following submatrix:

	G(r)DGR	G(r)GPL01	T(r)GPLOVC	N(r)DGP
G(r)OVC	-x		x	
G(r)DGP	x	-x		
G(r)LOS	-x	-x		
G(r)(xxx)		x		
G(r)CC1	-x			x
OBJ			-x	

nrfplant.f (Continued)

	G(r)NATOTH	G(r)NATPCF	G(r)(xxx)*LPG	G(r)(xxx)**RFN
G(r)(xxx)	-x	-x	-x	-x
OBJ	-x	-x	-x	-x
A(r)GPLPG	x	x	x	
A(r)NGLRFN				x
A@NGLRFN				x
B(r)(xxx)**				x
M(r)(prd)***			x	
A(r)NGLPRD	x	x	x	x
A@NGLPRD	x	x	x	x

nrfplant.f (Continued)

	G(r)SC2CC1	G(r)SC3CC1	G(r)METRFN	G(r)METDEM
G(r)CC1	x	x		
G(r)CC3		-x		
G(r)LOS	x	x		
G(r)PGS	-x			
OBJ	x	x	-x	-x
A(r)NGSMER			x	
A@NGSMER			x	
B(r)MET			x	
G(r)MET			-x	-x
D@MET				x

nrfplant.f (Continued)

	E(r)MOHINV	L(r)MOHBLD	K(r)MOHCAP	G(r)MOH01
L(r)MOHCAP	-x	-x	-x	x
G(r)MET				x
G(r)OVC				-x
U(r)NGF				-x
A(r)NGSMET				x
A@NGSMET				x
A@METPRD				x
OBJ	-x	-x		
A(r)INVST	x			
A@INVST	x			
A(r)FXOC	x	x		
A@FXOC	x	x		

(xxx) : PGS, CC3, IC4, NC4, NAT
* : (xxx) except NAT ; **: (xxx) except PGS, CC3; *** LPG, OTH, PCF

Bounds: G(r)SC3CC1, N(r)DGP, E(r)MOHINV, K(r)MOHCAP

output.f: This subroutine prints reports.

prdexp.f: Simulates product exports. It creates the following submatrix:

	D(z)(prx)*SX	D(z)COKSX	D(z)ASTSX
D(z)(prx)	-x	-x	-x
OBJ	x	x	
A@COKEXP		x	
A(d)PRDEXP	x		x
A@PRDEXP	x		x

*: All (prx) except COK and AST; (z) = export demand regions (d) 2,3,7,8,9

Bounds: D(z)(prx)SX, except for (prx) = COK

prdimprt.f : This subroutine simulates product imports. It creates the following submatrix:

	I(r)(pri)*R(s)	I(r)(pri)**R(s)
A@(pri)*IMP	x	
A(r)(pri)*IMP	x	
B(r)(pri)*	x	
A(r)(pri)RFN	x***	
A(r)PRDIMP		x
A@PRDIMP		x
M(r)(pri)**		x
OBJ	-x	-x

* : for (pri) = MET and MTB; **: for all (pri) except MET and MTB;
*** for (pri) = MTB only; (s) = import steps 1-3 or 1-9

Bounds: I(r)(pri)Rn

recipes.f: This subroutine simulates product recipe blending. It creates the following submatrix:

	X(r)(xxx)(yyy)	X(r)(yyyy)
B(r)(ist)	-x	-x
M(r)(yyy)	x***	x
OBJ	x	-x*
U(r)STM		-x**
A(r)(yyy)	x***	x

	X(r)(xxx)(yyy)	X(r)(yyyy)
A(r)SULSAL	x****	
A@SULSAL	x****	
A(r)PETCOK	x***	
A@PETCOK	x***	
A@PRDRFN	x***	x

(xxx) = AST, AVG, CKH, CKL, GOP, SUL ; (yyy) = AST, OTH, COK, PCF, SAL
(yyyy) = AST0, AST1, AVG0, GOP0;
: for (yyyy) = AVG; **: for (yyyy) = AST0; ***: for (yyy) = COK; **** for (yyy) = SAL

refproc.f: This subroutine simulates the refinery processes. It creates the following submatrix:

	E(r)(uns)INV	K(r)(uns)CAP	L(r)(uns)BLD	T(r)OVCOBJ	R(r)(uns)(mod)
OBJ	-x		-x	-x	
B(r)(ist)					+-x
L(r)(uns)CAP	-x	-x	-x		x
U(r)(uuu)					+-x
P(r)(pol)				x*	+-x
P(r)CBNTAX					-x
M(r)(mod)					-x
A(r)INVST	x				
A@INVST	x				
A(r)FXOC	x		x		
A@FXOC	x		x		
A(r)GAIN					+-x
A@GAIN					+-x
A(r)METRFN					x**
A(r)NGSH2P					x***
A@NGSH2P					x***
A@MTBPRD					x****

*: when (pol) = OVC; **: when (uns) = ETH; ***: when (uns) = H2P; ****: when (uns) = ETH and (mod) = MTB

Bounds: K(r)(uns)CAP, E(r)(uns)INV, L(r)(uns)BLD

setrows.f: This subroutine sets the row types (G, L, E, N) for rows P(r)(pol).

splash.f: This subroutine simulates splash blending. It creates the following submatrix:

	X(d)ETH(xxx)	X(d)METM85	X(d)(www)SPG	B(r)RFG(sss)	B(r)RFG(rrr)
D(d)(xxx)	x	-x****			
D(d)ETH	-x				
D(d)(yyy)	-x				
D(d)M85		x			
D(d)MET		-x			
A(d)G08(xxx)	x*				
A@ETH(xxx)	x				
A@METM85		x			
A(d)RFG(xxx)** not linked to col					
A(d)TRG(xxx)	x***				
D(d)(www)			x		
D(d)(ttt)			-x		
Q(r)RFGREN	x**			x	
S(r)RFGOXY	x**				x

(rrr) = ETB, MTB, TAE, TAM, THE, THM; (sss) = ETB, TAE, THE;
(ttt) = N6B, N6I; (www) = N67, N68; (xxx) = E85, RFG, RFH, TRH, TRG;
(yyy)=SSR when (xxx)=RFG, RFH and (yyy)=SST when (xxx)=TRH and
(yyy)=SSE when (xxx)=TRG;
*: (xxx) not equal to E85; **: (xxx)=RFG, RFH only;
:(xxx)=TRG, TRH only; *:(xxx)=TRG only

Bounds: none.

stream.f: This subroutine simulates stream transfers. It creates the following submatrix:

	T(r)(ist)(ist)	T(r)(ist)(prd)
B(r)(ist)	+-x	-x
M(r)(prd)		x
A(r)(prd)		x

	T(r)(ist)(ist)	T(r)(ist)(prd)
A@PRDRFN		x

tabread.f: This subroutine prints the data file names, the number of tables and lists the tables names that are read.

transit5.f: This subroutine simulates the transportation network for MRM 5-region

	Y(o)*(crt)(m)(r)	W(d)ETH(r)	W(r)MET(d)	W(s)(prd)(d)	V(xxxxxx)
C(o)(crt)	-x				
C(r)(crt)	+-x				
OBJ	-x	-x	-x	-x	
TVC(m)CP	x				
TPC(o)*(m)(r)	x				
B(r)ETH		x			
D(d)ETH		-x			
D(r)ETH		x**			
A(r)ETHRFN		x			
B(r)MET			-x		
D(d)MET			x		
M(s)(prd)				-x	
M(d)(prd)				x	
TPL(s)(m)(d)				x****	
TPP(s)(m)(d)				x***	
D(d)(prd)				x	
TVP(m)CP				x	
(xxxxxx)					-x

* OGSM supply (o) and PADD (r) regions; ** for (r)=Census Division
*** for (prd) different than MET, ETH; **** for (prd) = LPG and PCF;
(s) : PADD (r) and demand (d) regions; (xxxxxx) = TVC5CP, TVPJCP, ...

Bounds: V(xxxxxx)

unfinished.f: This subroutine simulates the unfinished oil process. It creates the following submatrix:

	T(r)UNF(ist)	T@UNFTOT
B(r)(ist)	x	
F(r)UNF(ist)	-x	x
OBJ	-x	
A(r)UNF	x	
A@UNFIMP	x	
A(r)UNFIMP	x	
F@TOTCRD		-x

utility.f: This subroutine represents the utility. It creates the following submatrix:

	U(r)(uuu)	R(r)KWGPGN	T(r)NGFNGS
U(r)(uuu)	x	x**	-x***
OBJ	-x		
A@KWHRFN	x*	x	
B(r)NGS			x
A(r)NGSRFN			x
A@NGFTOT	x***		
A(r)NGFTOT	x***		
Z(r)NGFSUM	-x***		

*: for (uuu) = KWH ; **: for (uuu) = KWH and STM; ***: for (uuu) = NGF

utilitye.f: This subroutine is the same as utility.f, except that it is for ERM, and (r)=PADD G only.

All the Fortran files are located in /refine/db6/mrm/default/source/

G.2.c Common Blocks

Variables shared by several subroutines are set up in common. There are four files that contain the common blocks used by the program. Some of the files consists of several common blocks.

The following table lists the common block names, gives a brief description and the location of the block.

Common	Description	Location
IPMMREAL	Common for real variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest

Common	Description	Location
IPMMINT	Common for integer variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest
IPMMCHAR	Common for character variables shared by subroutines that generate submatrices	/refine/db6/mrm/default/data/ipmmtest
LPTAB	Common used for solution retrieval and report writing	/refine/db6/mrm/default/data/lpout
DFINC2	Common for OML database functions	/default/includes/dfinc2
CR	Common for the WHIZ optimizer	/default/includes/wfinc2

A list of the common blocks and the variables that constitute them is given in Appendix D.

G.3 Data

Most of the data that the program uses is provided in files with a .dat extension. There is a one to one correspondence between the Fortran files that form part of the matrix and the .dat data files (ex accunit.f gets its input from accunit.dat) . In each of the .dat files, the data is arranged in an OML format that consists of tables. Each table consists of a table name; row or stub and column or head names; and values at the intersection of rows and columns. In addition there are ASCII files. These ASCII files are for control of the program. The following is the description of each input file.

G.3.a Data sets

.dat files

accunit.dat

Table Name	Columns	Rows	Description
ACUCUTS	(crt)	(ist)	Crude distillation yield
ACUPOL	OVC, LOS	(crt)	ACU policy table
ACUUTI	(uuu)*	(crt)	ACU utility consumption
INVLIM	MAX	(r) , @	Maximum investment

* except NGF

akaexp.dat

Table name	Columns	Rows	Description
EXPAKA	P, Q	N1, N2, N3, P4, P5, P6	Price and quantity of Alaskan crude exports.
NGLAKA	PER	PGS, CC3, NC4, IC4, and NAT	Yield of NGL

Table name	Columns	Rows	Description
PRQAKA	VOL, TRP, EXPPRC	A	Volume, and transportation and expected cost for Alaskan crude exports

avoids.dat (no longer used)

Table	Columns	Rows	Description
SADELPX	FACTORS	N1, N2, N3, P1, P2, P3	Price differentiate
PRDAVOID	DUMMY	(prd)	Product list
SADELQ	N1, N2, N3, P1, P2, P3	(prd)	Demand shift quality fraction

cogener.dat

Table	Columns	Rows	Description
CGNCAP	CAP, PUL, BLD	(r)	Cogeneration capacity, %utilization and build
CGNINV	INV, FXOC, CAPREC	(r)	Cogeneration investment, fixed cost and capital recovery
CGNPOL	OVC	CGN	Cogeneration policy
CGNREP	CGN	FUL	Cogeneration yields
CGNUTI	(uuu)*	(r)	Cogeneration utility usage
SELGEN	SOLD	(r)	% cogeneration sold to grid

* except NGF

cogenere.dat

Table	Columns	Rows	Description
CGNCAP	CAP, PUL, BLD	G	Cogeneration capacity, %utilization and build
CGNINV	INV, FXOC, CAPREC	G	Cogeneration investment, fixed cost and capital recovery
CGNPOL	OVC	CGN	Cogeneration policy
CGNREP	CGN	FUL	Cogeneration yields
CGNUTI	(uuu)*	G	Cogeneration utility usage
SELGEN	SOLD	G	% cogeneration sold to grid

* except NGF

crdimprt.dat

Table	Columns	Rows	Description
CRUDETYPE	DUMMY	(crt)*	Foreign crude types
ICR(crt)*(r)	C1, Q1, C2, Q2, C3, Q3	(year)	Price and quantity available for crude imports.

*: for (crt) = FLL, FMH, FHL, FHH, FHV (i.e. foreign crudes)

demand.dat

Table	Columns	Rows	Description
CKSMIX	CKL, CKH	OBJ, CKL, CKH, COK	Coke price and conversion factor
PRODLIST	DUMMY	(prd)	List of products
(prd)*	(d)	(year)	Product (prd) demand
DEMMET	CHEM	(year)	MET demand

* RFH mapping and corresponding table renamed to RFHA due to duplicate table name elsewhere.

distblnd.dat

Table	Columns	Rows	Description
Q(r)DFO	(dfo)	(spec)	Distillate fuel oil blend specs
DFOUTI	STM	(dfo)	Distillate blend steam use.
DCC	(mod)	(ist)	Distillate recipe blend.
DCB	spec categories *	(ist)	Distillate blend intermediate stream quality specification.

* from Z:MAPDFOSP

distress.dat

Table	Columns	Rows	Description
ZPX	Value	(prd)	Distress code for pricing

domcrude.dat

Table	Columns	Rows	Description
DCRSUP	(o)	Y95	Historical crude supplies by OGSM region
DCRSHR	(o)	(crt)*	Domestic crude share by OGSM region
CREXP	CRDEXP, CRDSPR	VOL	Crude exports and SPR

*: (crt) except FLL, FMH, FHL, FHH, FHV

emish.dat

Table	Columns	Rows	Description
EMUNS	(emu)*	Process unit	Emission by process unit
EMFUM	(emu)	Fuel stream burned	Emission by fuel burned

* except CO2

ermcrude.dat

Table	Columns	Rows	Description
CRUDEG	CST, MIN, MAX	(crt)	Crude cost and volume limits

ermother.dat

Table	Columns	Rows	Description
OTHERG	CST, MIN, MAX	(ncr)	Non crude cost and volume limits

ermprod.dat

Table	Columns	Rows	Description
PRODUCTG	REV, MIN, MAX	(prd)	Product revenue and volume limits

ethanol.dat

Table	Columns	Rows	Description
SUPETH(d)	C1, R1, C2, R2, C3, R3	(year)	Ethanol supply curves
ETHTAX	TAX	(d)	Ethanol taxes

fixcols.dat (no longer used)

Table	Columns	Rows	Description
FIXCOL	R	Dummy	First letter of column to fix
(r)RCOL	FCC	(mod)	Column to fix to zero

fuelmix.dat

Table	Columns	Rows	Description
GROUP	DUMMY	Fuel stream	List of fuel stream

gasoblnd.dat

Table	Columns	Rows	Description
Q(r)GSL	TRG, RFG	(spec)	TRG, RFG specs
(r)SSR	SSR, RFH	RFG(spec)	Gasoline specs for subspec SSR
(r)SST	SST, TRH	TRG(spec)	Gasoline specs for subspec SST
(r)SSE	SSE, TRG	TRG(spec)	Gasoline specs for subspec SSE
GASGROUP	TEXT(1)	(ist)	List of blending streams specially grouped
GCB	Quality codes	(ist)	Gasoline blend intermediate stream quality specification.
GCC	Gasoline type	(ist)	Gasoline recipe blend.
MCO	Motor octane codes*	(ist)	Gasoline component base octane ratings
(xxx)BV	Motor octane codes**	(ist)	Gasoline component blending values
GSLUTI	KWH	(prd), SSE, SST, SSR	Gasoline utility use.
GSPETH	RE	RFGN	Gasoline specs for ETH

(spec) = 2 character quality code followed by X (maximum) or N (minimum).
(xxx) = UNC and RFM (representing TRG and RFG, respectively).
* R00, R05, R15, R30, M00, M05, M15, M30, of which only R00 and M00 are used by the PMM.
** same as *, except column TEL added (but not used by the PMM).

limpol.dat

Table	Columns	Rows	Description
UNITPOL	DUMMY	(uns)	List of processes that have a limit on POL
LIM(uns)(r)	(ist)	DUM	Limit on (ist)

main.dat

Table	Columns	Rows	Description
EXPROD	DUMMY	(prx)	List of product exports
INVFACT	LOC, ENV	(r)	Location and environment factors

Table	Columns	Rows	Description
TRSOVC	OVC	(r)	Conversion factor for operating cost
FORCRD	DUMMY	(crt)*	List of foreign crudes
YRDOLLAR	1991	1987	Conversion factor
ZIRACFAC	Delta	ZIRAC	Range of price differential for IRAC
WOP	WOP	(year)	World oil price
RFNREG	PAD	(r)	List of PADDs
RFNEXP	RFID	Linked list of refinery and export regions	List of exporting regions
DEMNDREG	REGION	List of demand regions	List of demand region
USERYEAR	YEAR	YR95	Year to run model

* FFL, FMH, FHL, FHH, FHV

maine.dat

Table	Columns	Rows	Description
EXPROD	DUMMY	(prx)	List of product exports
INVFACT	LOC, ENV	G	Location and environment factors
TRSOVC	OVC	G	Conversion factor for operating cost
FORCRD	DUMMY	(crt)*	List of foreign crudes
YRDOLLAR	1991	1987	Conversion factor
ZIRACFAC	Delta	ZIRAC	Range of price differential for IRAC
WOP	WOP	(year)	World oil price
RFNREG	REFINERY	G	List of PADDs
DEMNDREG	REGION	GG	List of demand region
USERYEAR	YEAR	YR95	Year to run model

* FFL, FMH, FHL, FHH, FHV

mchproc.dat

Table	Columns	Rows	Description
MCHINV	INV, FXOC, CAPREC	(uns)	Merchant plant investment, fixed cost and capital recovering

Table	Columns	Rows	Description
(r)CAPMCH	CAP, PUL, BLD	(uns)	Merchant plant processes capacity, % utilization and build.
(uns)POL	(pol)	(ist)	Merchant plant processes policy
(uns)CAP	(uns)CAP	(ist)	Merchant plant process capacity
(uns)REP	(ist)	(ist)	Merchant plant process yields
(uns)UTI	(uuu)	(ist)	Merchant plant process utility usage
TRANSFER	Dummy	GP, MP, RF	Transfer allowed
RFTRANS	MP	(ist)	Refinery transfer to merchant plant
GPTRANS	MP	(ist)	Gas plant transfer to merchant plant
MPTRANS	GP, RF	(ist)	Merchant plant transfer to gas plant and refinery
(r)UAP	CST	(uuu)	Utility purchases

ngprod.dat

Table	Columns	Rows	Description
SPNGF	ALLREG	N1, .., N4, P5, ..., P8	Price steps for gas supply
SQNGF	MAX, MIN	N1, .., N4, P5, ..., P8	Quantity steps for gas supply
SCVAL	(r)	VOL	Volume limits on each step

nrfplant.dat

Table	Columns	Rows	Description
INVMOH	INV, CAPREC, FXOC	MOH	Non refinery plant process investment, capital recovery, and fixed cost.
MOHPLT	(r)01	CC1, MET, OVC	Production of methanol
MOHCAP	(r)01	CAP	Methanol capacity
GASPLT	(r)01	(ist), (pol)	Yield from gas plant
GASSHFT	SC2, SC3	CC1, LOS, OBJ	Shift from ethane and propane to methane
GASCAP	(r)01	CC1, FAC, CAP, LIM, PCU	Gas plant capacity limits

prdexp.dat

Table	Columns	Rows	Description
(x)PRDEXP	VOL	(prx)	Limit on volume to export

Table	Columns	Rows	Description
EXPLIM	YRPC, FIX	1995	Limit on volume and yearly increase
MULTEXPR	MULT	PRICE	Price for exports as function of imports

prdimprt.dat

Table	Columns	Rows	Description
PRODTYP	DUMMY	(pri)	List of product import
IMPLIM	MAX	@	Maximum imports into USA
IPR(pri)(r)	C1, R1, ..., C3, R3	(year)	Product import supply curve
NEMSRSD	R1B, R1PR	R1, ..., R9	Resid import supply curve

recipes.dat

Table	Columns	Rows	Description
RCPEIA	A, CST, JTA, N2H, SLP, CKH, CKL	KERSPG, SULSAL, CKHCOK, CKLCOK	Cost of sulfur and coke; kerosene split; unit conversions.
RCP	A, CST, component stream, STM	Recipe blended products	Recipe blends.

refproc.dat

Table	Columns	Rows	Description
(r)CAP	CAP, PUL, BLD	(uns)	CAP, PUL and BLD values
(uns)	(mod)	(ist), (uuu), CAP, (pol)	Refinery process yields, utility usage, capacity factor, policy
MATBAL	A	(ist)	Streams requiring material balance
INV	INV, FXOC, CAPREC	(uns)	Refinery processes investment, fixed cost and capital recovery

setrows.dat

Table	Columns	Rows	Description
(r)POL	TYPE	(pol)	Row type

splash.dat

Table	Columns	Rows	Description
HOXETH	TRH, RFH, RFG,TRG	Gasoline blend stream	Ethanol recipe for splash blending
BLNSP(d)	KER, N67, N68	JTA, N2H, KER, N6I, N6B, N67, N68	Blend composition recipe
BLOX(d)YXX	E85, M85, TRH, RFH, RFG, TRG	Gasoline stream	Recipe blend composition
XETH	PO	XETH	Oxygen content of ethanol
SCB	PO	Oxygenate stream	Oxygen content of oxygenates

stream.dat

Table	Columns	Rows	Description
XSALE	DUMMY	(ist)(prd)	Linked list of stream transfer to products
TRS	MIN, CST	(ist)(ist)	Linked list of stream to stream transfers

transit.dat

Table	Columns	Rows	Description
MVCCAP	MAX	TVC(m)CP, TVP(m)CP	Marine vessel capacity for crude & product
BVPCAP	MAX	TVP(m)CP	Marine barge capacity for product
PLCCAP	MAX	TPC(o)*(m)(r) TPP(r)**(m)(d) TPL(r)**(m)(d)	Pipeline capacity for (C) crude (P) product (L) LPG
TPCRLIST	DUMMY	(o)	Crude supply regions for transportation
TPCR(o)	(crt)	(XY) where X is mode and Y is refinery region	Crude oil transportation cost from supply region (r)
PLCRLIST	DUMMY	(o)*	List of crude oil supply regions for pipeline
PLCR(o)*	(crt)	(m)(r)	Crude pipeline transportation cost
BVPR(r)	(prd)	(m)(d)	Product barge/truck transportation cost
TPPR(r)	(prd)	(m)(d)	Product marine transportation cost
TPME(r)	MET	(m)(d)	Methanol transportation cost
TPETLIST	DUMMY	(d)	List of Census Divisions for ethanol transportation
TPET(d)	ETH	(m)(r)**	Ethanol transportation cost
PLPRLIST	DUMMY	(d)	List linked census divisions for product pipeline from region G to East Coast
PLPR(r)**	(prd), SSE, SST, SSR	(m)(d)	Product pipeline transportation cost

Table	Columns	Rows	Description
PLLG(r)	LPG, PCF	(m)(d)	LPG transportation cost
PLNKLIST	DUMMY	(r)**	List of product pipeline originations.
PLNK(r)**	(prd), SSE, SST, SSR	(m)(r)**	Product pipeline transport connections and costs

* OGSM supply (o) and refinery (r) regions
** PADD (r) and demand (d) regions

unfinish.dat

Table	Columns	Rows	Description
UNFOIL	E, G, PD	streams: NPP, HGM, ARB	Types (3) of unfinished oil imports into the U.S.
UNFEQT	SLOPE, CONST	XYZ	eq. parameters that correlate unfinished oil imports to crude input

utility.dat

Table	Columns	Rows	Description
UTITRS	COEF	NGFNGS	BFOE natural gas.
(r)UAP	CST	(uuu)	Utility costs.
VALPNG	(r)	(year)	Industrial price of natural gas.

utilitye.dat

Table	Columns	Rows	Description
UTITRS	COEF	NGFNGS	BFOE natural gas.
GUAP	CST	(uuu)	Utility costs.

G.3.b Other input files

1. **mrmparam** file

The mrmparam file[1] is a control file read by main.f to map input and output file names and instructions. In the mrmparam, the user chooses the model that he wants to run; the names for the actproblem, solution, path file, basis, mps file, and packed matrix; the model title; and the location and name of the starting basis and optimal basis. The following table lists the information that is to be supplied in the mrmparam file.

[1]Note that the default file used for the MRM is named "mrmparam," while that used for the ERM is named "ermparam." Before an ERM execution can be run, the ermparam name must be renamed to mrmparam.

Variable name	Variable length	Variable purpose	Restrictions
MODELN	8	Model to be run	MRM5, ERM
ACTPROB	8	Act problem	
SOLNAME	8	Solution name	
PATHNF	7	Name of file where data files paths are stored.	
TITLE	40	Problem title	
INBASISN*	40	Location and name of advanced basis	
OUTBASIS	8	Name of optimal basis	
BASISN	8	Basis name	
MPSOUTN**	8	MPS file name	
PAKCN**	8	Packed matrix file name	.PCK extension

*: If no name or a file does not exist, the program will operate without an advanced basis.
**: if "NULL" or "null" is provided, the program will skip the part of the program that generates the file.

The above variables have to be provided in the order they are listed in the above Table and should start at column 18. In the Appendix G-A we provide an example of an mrmparam file. The mrmparam file has to be in the subdirectory where the model is executed.

2. **path** file:

In this file the user provides the program with the location and name of the data files. The order in which the names appear is important. See Appendix G-B for an example of a path file. The path file has to be in the directory from which the model is executed. This file format is that of an OML table.

3. **Advanced basis** file:

In this file the user provided an advanced basis to the model. If the user does not provide one or provides one whose name does not coincide with the basis name provided in the mrmparam, the program will not use it.

G.4 Submission of a Run

In order to run the model, one has to first compile and link the different FORTRAN source files to form an executable. Once the executable is created, the user submits a run by providing an mrmparam and a path file. The execution of the program will solve the problem and create:

- An ACTFILE file
- An MPS file
- A SYSPRINT file (solution)

- An out basis file
- A packed matrix file
- Reports (only for MRM5)

The following are the files created by a run:

	ERM	MRM
ACTFILE	ACTFILE.act	ACTFILE.act
MPS file	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Solution file	SYSPRINT	SYSPRINT
Out basis	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Packed matrix	Name provided by user in the mrmparam file	Name provided by user in the mrmparam file
Report	None	reports5, fort.75

All the files used for MRM and ERM matrix generation reside within the NEMS default directories on EIA's RS-6000, as defined next. The source files that encompass the program are on /default/source/, and the object codes are on /default/objects/. The user must link the object files to form the mrm executable to be located in the user's directory. A makefile (/default/scripts/mrmmakefile) is used by the user to form the executable.

The mrmparam file and the mrmpath file used for the MRM model are located in the /default/scripts/ directory. The ermparam file and the ermpath file used for the ERM model are located in the /default/input/ directory. To run each of the models, their respective param and path files must be copied to the user directory. Also remember that the ermparam file must be renamed to mrmparam in the user directory prior to model execution. The path files point to the default data files (*.dat) that are stored in /default/input/ directory.

Runs

1. In order to run the default (no changes)
   a. Copy the **mrmmakefile** and the appropriate **param** and **path files** to your own directory.
   b. (If running ERM, rename the ermparam to **mrmparam**.)
   c. Create an executable by typing: **make -f mrmmakefile**
   d. Run the executable by typing: **nohup mrm &**

2. If you want to make changes to a data file
   a. Copy the **mrmmakefile,** the appropriate **param** and **path files**, and the **data file** to your own directory.
   b. (If running ERM, rename the ermparam to **mrmparam**.)
   c. Create an executable by typing: **make -f mrmmakefile**
   d. Make changes to the **data file**.
   e. Modify the **path file** to specify the path of the modified file.

f. Run the executable by typing: **nohup mrm &**

3. If you want to make changes to a source file
   a. Copy the **mrmmakefile,** the appropriate **param** and **path files**, and the **source file** to your own directory.
   b. (If running ERM, rename the ermparam to **mrmparam**.)
   c. Make changes to the **source file**.
   d. Modify the **mrmmakefile** as follows:
      --add after **SIR=** and **LIR=**:
      SIR2= /YOURSOURCE/INPUTDIRECTORY/
      LIR2= /YOURSOURCE/INPUTDIRECTORY/
      --search for the name of the **source file** being changed
      -change SIR and LIR to SIR2 and LIR2, respectively
      -remove version reference from the *.o names
   e. Create an executable by typing: **make -f mrmmakefile**
   f. Run the executable by typing: **nohup mrm &**

Appendix G-A: Example of an mrmparam file.

mrmparam:

```
MODELN        'MRM5    '                                        !8
ACTPROB       'OMLMRM5 '                                        !8
SOLNAM        'MRM5SOL '                                        !8
PATHNF        'mrmpath'                                         !7
TITLE         'MRM5 MULTI  REGION  REFINERY                  '      !48
INBASISN      'inbasis5                                      '      !48
OUTBASISN     'outbasis5'                                       !9
BASISN        'MRM5     '                                       !9
MPSOUTN       'mrm5mps  '                                       !9
PACKN         'NULL     '                                       !9
```

ermparam:

```
MODELN        'ERM     '                                        !8
ACTPROB       'OMLERM  '                                        !8
SOLNAM        'ERMSOL  '                                        !8
PATHNF        'pathe   '                                        !7
TITLE         'ERM  SINGLE REGION  REFINERY                  '      !48
INBASISN      '/refine/pmm_lp_gen/data/erm/inbasise          '      !48
OUTBASISN     'outbasise'                                       !9
BASISN        'ERM      '                                       !9
MPSOUTN       'ermGmps  '                                       !9
PACKN         'ERM2.PCK '                                       !9
```

The mrmparam file will run the 5-region MRM model and the ermparam file will run the single region ERM model; the act problem will be “OMLMRM5" for the MRM model and “OMLERM “for the ERM model; the solution name will be “MRM5SOL” for the MRM model and “ERMSOL” for the ERM model; the data

files path will be read from the file “mrmpath" for the MRM model and “pathe” for the ERM model; the title of the MRM model will be “MRM5, MULTIPLE REGIONS REFINERY” and the ERM model will be “ERM, SINGLE REGION REFINERY;” the advanced basis will be read from “inbasis5" for the MRM model and “inbasise” for the ERM model along the path defined; the optimal basis will be stored in the file “outbasis5" for the MRM model and “outbasise” for the ERM model; both the advanced and optimal basis will be named “MRM5" for the MRM model and “ERM for the ERM model; the mps file will be stored in “mrm5mps” for the MRM model and “ermGmps” for the ERM model; and the packed matrix will not be created (NULL) for the MRM model, but will be stored in “ERM2.PCK” for the ERM model.

Remember that the “ermparam” file must be **renamed** to “mrmparam” before an ERM execution can be run.

Appendix G-B: Example of a path file

mrmpath:

```
NAME          PATHDATA
        DATA    Z:PATHNAME
**       TEXT(6)
accunit     /default/input/accunit.dat.v1.4
avoids      /default/input/avoids.dat.v1.1
cogener     /default/input/cogener.dat.v1.4
crdimprt    /default/input/crdimprt.dat.v1.2
demand      /default/input/demand.dat.v1.3
distblnd    /default/input/distblnd.dat.v1.2
distress    /default/input/distress.dat.v1.2
domcrude    /default/input/domcrude.dat.v1.1
emish       /default/input/emish.dat.v1.1
ethanol     /default/input/ethanol.dat.v1.1
fixcols     /default/input/fixcols.dat.v1.2
fuelmix     /default/input/fuelmix.dat.v1.2
gasoblnd    /default/input/gasoblnd.dat.v1.4
main        /default/input/main.dat.v1.2
ngprod      /default/input/ngprod.dat.v1.1
nrfplant    /default/input/nrfplant.dat.v1.4
prdimprt    /default/input/prdimprt.dat.v1.1
recipes     /default/input/recipes.dat.v1.2
refproc     /default/input/refproc.dat.v1.14
setrows     /default/input/setrows.dat.v1.3
splash      /default/input/splash.dat.v1.4
stream      /default/input/stream.dat.v1.3
transit     /default/input/transit.dat.v1.4
utility     /default/input/utility.dat.v1.3
mchproc     /default/input/mchproc.dat.v1.4
limpol      /default/input/limpol.dat.v1.2
unfinished  /default/input/unfinish.dat.v1.1
prdexp      /default/input/prdexp.dat.v1.1
akaexp      /default/input/akaexp.dat.v1.1
foreign1
foreign2
fsu
intsetup
epsetup
bldhead
bldstub
ENDATA
```

pathe:

```
NAME          PATHDATA
         DATA    Z:PATHNAME
**        TEXT(6)
accunit     /default/input/accunit.dat.v1.4
avoids
cogener     /default/input/cogenere.dat.v1.1
crdimprt
ermprod     /default/input/ermprod.dat.v1.1
distblnd    /default/input/distblnd.dat.v1.2
distress
ermcrude    /default/input/ermcrude.dat.v1.1
emish
ethanol
fixcols
fuelmix     /default/input/fuelmix.dat.v1.2
gasoblnd    /default/input/gasoblnd.dat.v1.4
main        /default/input/maine.dat.v1.1
ngprod
ermother    /default/input/ermother.dat.v1.1
prdimprt
recipes     /default/input/recipes.dat.v1.2
refproc     /default/input/refproc.dat.v1.14
setrows     /default/input/setrows.dat.v1.3
splash
stream      /default/input/stream.dat.v1.3
transit
utility     /default/input/utilitye.dat.v1.1
mchproc
limpol      /default/input/limpol.dat.v1.2
unfinished
prdexp
akaexp
foreign1
foreign2
fsu
intsetup
epsetup
bldhead
bldstub
ENDATA
```

Appendix G-C:Makefile

```
FLAGS= -c -g -C -qcharlen=16384 -qmaxmem=-1 -qnoprint \
      -qflttrap=zerodivide -qsave
INC= -I/refine/pmm_lp_gen/includes/ -I/default/includes
LIBS= -lwhiz -ldb -lutil -L/usr/lpp/MPS/oml/lib
DIR= /default/objects/
SIR= /default/source/
LIR= /default/objects/
OMLSPA = /refine/pmm_lp_gen/includes/omlspace \
       /refine/pmm_lp_gen/includes/ipmmtest
OBJS= $(LIR)mrm.v1.2.o \
      $(LIR)extpnt.v1.2.o \
      $(LIR)epadjust.v1.2.o \
      $(LIR)bldhead.v1.2.o \
      $(LIR)bldstub.v1.2.o \
      $(LIR)intsetup.v1.2.o \
      $(LIR)foreign.v1.2.o \
      $(LIR)fsu.v1.2.o \
      $(LIR)akaexp.v1.2.o \
      $(LIR)prdexp.v1.3.o \
      $(LIR)unfinished.v1.2.o \
      $(LIR)lplookup.v1.2.o \
      $(LIR)output.v1.2.o \
      $(LIR)ermcrude.v1.2.o \
      $(LIR)ermother.v1.2.o \
      $(LIR)ermprod.v1.2.o \
      $(LIR)tabread.v1.2.o \
      $(LIR)limpol.v1.2.o \
      $(LIR)mchproc.v1.4.o \
      $(LIR)crdimprt.v1.2.o \
      $(LIR)accunit.v1.5.o \
      $(LIR)refproc.v1.6.o \
      $(LIR)nrfplant.v1.2.o \
      $(LIR)stream.v1.2.o \
      $(LIR)distblnd.v1.2.o \
      $(LIR)gasoblnd.v1.3.o \
      $(LIR)domcrude.v1.2.o \
      $(LIR)demand.v1.3.o \
      $(LIR)utility.v1.2.o \
      $(LIR)utilitye.v1.2.o \
      $(LIR)cogener.v1.3.o \
      $(LIR)fuelmix.v1.2.o \
      $(LIR)recipes.v1.2.o \
      $(LIR)ethanol.v1.3.o \
      $(LIR)ngprod.v1.2.o \
      $(LIR)setrows.v1.2.o \
      $(LIR)fixcols.v1.2.o \
      $(LIR)transit3.v1.2.o \
      $(LIR)transit5.v1.2.o \
      $(LIR)prdimprt.v1.2.o \
      $(LIR)splash.v1.3.o \
      $(LIR)distress.v1.2.o \
      $(LIR)avoids.v1.2.o \
      $(DIR)omlanal.v1.6.o \
      $(LIR)emish.v1.2.o \
```

```
mrm: $(OBJS)
	xlf -o mrm -g -C $(OBJS) $(LIBS) -bloadmap:loadmap

$(LIR)mrm.v1.2.o: $(SIR)mrm.f $(OMLSPA)
	xlf $(FLAGS) -o $(LIR)mrm.v1.2.o $(INC) $(SIR)mrm.f
$(LIR)extpnt.v1.2.o: $(SIR)extpnt.f
	xlf $(FLAGS) -o $(LIR)extpnt.v1.2.o $(INC) $(SIR)extpnt.f
$(LIR)epadjust.v1.2.o: $(SIR)epadjust.f
	xlf $(FLAGS) -o $(LIR)epadjust.v1.2.o $(INC) $(SIR)epadjust.f
$(LIR)bldhead.v1.2.o: $(SIR)bldhead.f
	xlf $(FLAGS) -o $(LIR)bldhead.v1.2.o $(INC) $(SIR)bldhead.f
$(LIR)bldstub.v1.2.o: $(SIR)bldstub.f
	xlf $(FLAGS) -o $(LIR)bldstub.v1.2.o $(INC) $(SIR)bldstub.f
$(LIR)intsetup.v1.2.o: $(SIR)intsetup.f
	xlf $(FLAGS) -o $(LIR)intsetup.v1.2.o $(INC) $(SIR)intsetup.f
$(LIR)foreign.v1.2.o: $(SIR)foreign.f
	xlf $(FLAGS) -o $(LIR)foreign.v1.2.o $(INC) $(SIR)foreign.f
$(LIR)fsu.v1.2.o: $(SIR)fsu.f
	xlf $(FLAGS) -o $(LIR)fsu.v1.2.o $(INC) $(SIR)fsu.f
$(LIR)akaexp.v1.2.o: $(SIR)akaexp.f
	xlf $(FLAGS) -o $(LIR)akaexp.v1.2.o $(INC) $(SIR)akaexp.f
$(LIR)prdexp.v1.3.o: $(SIR)prdexp.f
	xlf $(FLAGS) -o $(LIR)prdexp.v1.3.o $(INC) $(SIR)prdexp.f
$(LIR)unfinished.v1.2.o: $(SIR)unfinished.f
	xlf $(FLAGS) -o $(LIR)unfinished.v1.2.o $(INC) $(SIR)unfinished.f
$(LIR)lplookup.v1.2.o: $(SIR)lplookup.f
	xlf $(FLAGS) -o $(LIR)lplookup.v1.2.o $(INC) $(SIR)lplookup.f
$(LIR)output.v1.2.o: $(SIR)output.f
	xlf $(FLAGS) -o $(LIR)output.v1.2.o $(INC) $(SIR)output.f
$(LIR)limpol.v1.2.o: $(SIR)limpol.f
	xlf $(FLAGS) -o $(LIR)limpol.v1.2.o $(INC) $(SIR)limpol.f
$(LIR)tabread.v1.2.o: $(SIR)tabread.f
	xlf $(FLAGS) -o $(LIR)tabread.v1.2.o $(INC) $(SIR)tabread.f
$(LIR)mchproc.v1.4.o: $(SIR)mchproc.f
	xlf $(FLAGS) -o $(LIR)mchproc.v1.4.o $(INC) $(SIR)mchproc.f
$(LIR)ermcrude.v1.2.o: $(SIR)ermcrude.f
	xlf $(FLAGS) -o $(LIR)ermcrude.v1.2.o $(INC) $(SIR)ermcrude.f
$(LIR)ermother.v1.2.o: $(SIR)ermother.f
	xlf $(FLAGS) -o $(LIR)ermother.v1.2.o $(INC) $(SIR)ermother.f
$(LIR)ermprod.v1.2.o: $(SIR)ermprod.f
	xlf $(FLAGS) -o $(LIR)ermprod.v1.2.o $(INC) $(SIR)ermprod.f
$(LIR)crdimprt.v1.2.o: $(SIR)crdimprt.f
	xlf $(FLAGS) -o $(LIR)crdimprt.v1.2.o $(INC) $(SIR)crdimprt.f
$(LIR)accunit.v1.5.o: $(SIR)accunit.f
	xlf $(FLAGS) -o $(LIR)accunit.v1.5.o $(INC) $(SIR)accunit.f
$(LIR)refproc.v1.6.o: $(SIR)refproc.f
	xlf $(FLAGS) -o $(LIR)refproc.v1.6.o $(INC) $(SIR)refproc.f
$(LIR)nrfplant.v1.2.o: $(SIR)nrfplant.f
	xlf $(FLAGS) -o $(LIR)nrfplant.v1.2.o $(INC) $(SIR)nrfplant.f
$(LIR)stream.v1.2.o: $(SIR)stream.f
	xlf $(FLAGS) -o $(LIR)stream.v1.2.o $(INC) $(SIR)stream.f
$(LIR)distblnd.v1.2.o: $(SIR)distblnd.f
	xlf $(FLAGS) -o $(LIR)distblnd.v1.2.o $(INC) $(SIR)distblnd.f
$(LIR)gasoblnd.v1.3.o: $(SIR)gasoblnd.f
	xlf $(FLAGS) -o $(LIR)gasoblnd.v1.3.o $(INC) $(SIR)gasoblnd.f
$(LIR)domcrude.v1.2.o: $(SIR)domcrude.f
	xlf $(FLAGS) -o $(LIR)domcrude.v1.2.o $(INC) $(SIR)domcrude.f
$(LIR)demand.v1.3.o: $(SIR)demand.f
	xlf $(FLAGS) -o $(LIR)demand.v1.3.o $(INC) $(SIR)demand.f
```

```
$(LIR)utility.v1.2.o: $(SIR)utility.f
	xlf $(FLAGS) -o $(LIR)utility.v1.2.o $(INC) $(SIR)utility.f
$(LIR)utilitye.v1.2.o: $(SIR)utilitye.f
	xlf $(FLAGS) -o $(LIR)utilitye.v1.2.o $(INC) $(SIR)utilitye.f
$(LIR)cogener.v1.3.o: $(SIR)cogener.f
	xlf $(FLAGS) -o $(LIR)cogener.v1.3.o $(INC) $(SIR)cogener.f
$(LIR)fuelmix.v1.2.o: $(SIR)fuelmix.f
	xlf $(FLAGS) -o $(LIR)fuelmix.v1.2.o $(INC) $(SIR)fuelmix.f
$(LIR)recipes.v1.2.o: $(SIR)recipes.f
	xlf $(FLAGS) -o $(LIR)recipes.v1.2.o $(INC) $(SIR)recipes.f
$(LIR)ethanol.v1.3.o: $(SIR)ethanol.f
	xlf $(FLAGS) -o $(LIR)ethanol.v1.3.o $(INC) $(SIR)ethanol.f
$(LIR)ngprod.v1.2.o: $(SIR)ngprod.f
	xlf $(FLAGS) -o $(LIR)ngprod.v1.2.o $(INC) $(SIR)ngprod.f
$(LIR)setrows.v1.2.o: $(SIR)setrows.f
	xlf $(FLAGS) -o $(LIR)setrows.v1.2.o $(INC) $(SIR)setrows.f
$(LIR)fixcols.v1.2.o: $(SIR)fixcols.f
	xlf $(FLAGS) -o $(LIR)fixcols.v1.2.o $(INC) $(SIR)fixcols.f
$(LIR)transit3.v1.2.o: $(SIR)transit3.f
	xlf $(FLAGS) -o $(LIR)transit3.v1.2.o $(INC) $(SIR)transit3.f
$(LIR)transit5.v1.2.o: $(SIR)transit5.f
	xlf $(FLAGS) -o $(LIR)transit5.v1.2.o $(INC) $(SIR)transit5.f
$(LIR)prdimprt.v1.2.o: $(SIR)prdimprt.f
	xlf $(FLAGS) -o $(LIR)prdimprt.v1.2.o $(INC) $(SIR)prdimprt.f
$(LIR)splash.v1.3.o: $(SIR)splash.f
	xlf $(FLAGS) -o $(LIR)splash.v1.3.o $(INC) $(SIR)splash.f
$(LIR)distress.v1.2.o: $(SIR)distress.f
	xlf $(FLAGS) -o $(LIR)distress.v1.2.o $(INC) $(SIR)distress.f
$(LIR)avoids.v1.2.o: $(SIR)avoids.f
	xlf $(FLAGS) -o $(LIR)avoids.v1.2.o $(INC) $(SIR)avoids.f
$(LIR)emish.v1.2.o  : $(SIR)emish.f
	xlf $(FLAGS) -o $(LIR)emish.v1.2.o $(INC) $(SIR)emish.f
```

Appendix G-D: Common Blocks

File: ipmmtest

```
C  $Header: /default/includes/RCS/ipmmtest,v 1.6.1.11 1995/07/17 19:59:11 db6 Exp $
      COMMON /IPMMREAL/MAX, MIN, VALUE, INFINITY,
     +       WOP,
     +       REALURYR, YRDOLLAR, ENV, LOC, OVCOST
      REAL*8      MAX(1000)
      REAL*8      MIN(1000)
      REAL*8      VALUE(1000)
      REAL*8      INFINITY
      REAL*8      WOP(26)
      REAL*8      REALURYR
      REAL*8      YRDOLLAR
      REAL*8      ENV(5)
      REAL*8      LOC(5)
      REAL*8      OVCOST(5)
      COMMON /IPMMINT/COUNT, DUMMY,
     +       I, IRET, IROWS, J, JCOLS, K, KROWS, NUMREG,EXPREGSS,
     +       USERYEAR, DMDREG, NUMYRS, DBPROBG, COMTAB1, COMTAB2
      INTEGER*4   COUNT
      INTEGER*4   DUMMY
      INTEGER*4   I
      INTEGER*4   IRET
      INTEGER*4   IROWS
      INTEGER*4   J
      INTEGER*4   JCOLS
      INTEGER*4   K
      INTEGER*4   KROWS
      INTEGER*4   NUMREG
      INTEGER*4   EXPREGSS
      INTEGER*4   USERYEAR
      INTEGER*4   DMDREG
      INTEGER*4   NUMYRS
      INTEGER*4   DBPROBG(22)
      INTEGER*4   COMTAB1(13)
      INTEGER*4   COMTAB2(13)
      COMMON /IPMMCHAR/HEAD, STUB, PROCESS, BND, CNAME,
     +  DECKNAME, LRNAME, OBJ, RHS, RNAME, RCHAR5, REGION,
     +  EXPREG, DEMNDREG, DEMNDPAD, PATH, FRCRD, EXPRD
      CHARACTER*8  HEAD(1000)
      CHARACTER*8  STUB(1000)
      CHARACTER*8  PROCESS(1000)
      CHARACTER*8  BND
      CHARACTER*8  CNAME
      CHARACTER*8  DECKNAME
      CHARACTER*8  LRNAME
      CHARACTER*8  OBJ
      CHARACTER*8  RHS
      CHARACTER*8  RNAME
      CHARACTER*5  RCHAR5
      CHARACTER*1  REGION(5)
      CHARACTER*2  EXPREG(5)
      CHARACTER*1  DEMNDREG(9)
```

```
      CHARACTER*1  DEMNDPAD(9)
      CHARACTER*48 PATH(40)
      CHARACTER*8 FRCRD(5)
      CHARACTER*8 EXPRD(11)
```

File: lpout

Common block used for report writing

```
C  LPOUT COMMON BLOCK FOR USE IN OML MATRIX SOLUTION
                                !
      REAL        PRDPRC(9,18)
      REAL        BASECAP(5,27)
      REAL        BASEUTL(5,27)
      REAL        INVCAP(5,27)
      REAL        INVUTL(5,27)
      REAL        TOTCAP(5,27)
      REAL        TOTUTL(5,27)
      REAL        TOTSUP(6)
      REAL        PUTL(5,27)
      REAL        RFCRDCR(6)
      REAL        RFCRDAKA(6)
      REAL        RFCRDL48(6)
      REAL        RFQICRD(6)
      REAL        RFIMCR(6)
      REAL        RFQISPR(6)
      REAL        RFIMTP(6)
      REAL        RFQEXCRD(6)
      REAL        RFPQNGL(6)
      REAL        RFQNGLRF(6)
      REAL        NGLRF(6)
      REAL        NGLMK(6)
      REAL        RFQPRCG(6)
      REAL        RFPQIPRDT(6)
      REAL        RFPQUFC(6)
      REAL        RFQEXPRDT(6)
      REAL        RFQPRDDM(11)
      REAL        QCDUPD(6)
      REAL        RFQDINPOT(6)
      REAL        RFETHD(6)
      REAL        RFMTBI(6)
      REAL        RFMETI(6)
      REAL        RFMETD(6)
      REAL        RFMETCHM(6)
      REAL        RFMETM85(6)
      REAL        RFMETETH(6)
      REAL        RFETHE85(6)
      REAL        RFETHETB(6)
      REAL        RFETHMGS(6)
      REAL        RFCRDOTH(6)
      REAL        OTHOXY(6)
      REAL        QPRDIMD(11,23)
      REAL        QPRDEXD(6,23)
      COMMON/LPTAB/PRDPRC,BASECAP,BASEUTL,INVCAP,INVUTL,TOTCAP,
     +TOTUTL,PUTL,RFCRDDCR,RFCrtAKA,RFCrtL48,RFQICRD,RFIMCR,
     +RFQEXCRD,RFPQNGL,RFQNGLRF,NGLRF,NGLMK,RFQPRCG,RFPQIPRDT,
     +RFPQUFC,RFQEXPRDT,RFQPRDDM,QCDUPD,RFQDINPOT,RFETHD,RFMTBI,
     +RFMETI,RFMETD,RFMETCHM,RFMETM85,RFMETETH,RFETHE85,TOTSUP,
```

```
     +RFQISPR,RFIMTP,RFETHETB,RFETHMGS,OTHOXY,QPRDIMD,QPRDEXD,
     +RFCRDOTH
```

File: DFINC2

Common block used for OML database functions

```
C  $Header: /default/includes/RCS/dfinc2,v 1.1 1995/03/14 16:22:27 dln Exp $
C
C    DATABASE.FH    FORTRAN FUNCTION DECLARATIONS
C
C$INCLUDE DWCPRAG.FH
C
      INTEGER DFINIT
      INTEGER DFOPEN
      INTEGER DFEND
      INTEGER DFCLOSE
      INTEGER DFDEL
      INTEGER DFLIST
C
      INTEGER DFPINIT
      INTEGER DFPDEL
      INTEGER DFPCPY
      INTEGER DFPLIST
      INTEGER DFPTDEL
      INTEGER DFPTCPY
      INTEGER DFPMDEL
      INTEGER DFPMCPY
      INTEGER DFPSDEL
      INTEGER DFPSCPY
      INTEGER DFPRTBI
C
      INTEGER DFTINIT
      INTEGER DFTNEW
      INTEGER DFTDIM
      INTEGER DFTDEL
      INTEGER DFTCPY
      INTEGER DFTSNDX
      INTEGER DFTHNDX
      INTEGER DFTNDX
      INTEGER DFTGET
      INTEGER DFTPUT
      INTEGER DFTSADD
      INTEGER DFTHADD
      INTEGER DFTSDEL
      INTEGER DFTHDEL
      INTEGER DFTDISP
C
      INTEGER DFMINIT
      INTEGER DFMEND
      INTEGER DFMSTAT
      INTEGER DFMCRTP
      INTEGER DFMCRSC
      INTEGER DFMCCSC
      INTEGER DFMCVAL
      INTEGER DFMMVAL
      INTEGER DFMCRHS
      INTEGER DFMCRNG
```

```
      INTEGER DFMCBND
      INTEGER DFMRRTY
      INTEGER DFMRRSC
      INTEGER DFMRCSC
      INTEGER DFMRVAL
      INTEGER DFMRRHS
      INTEGER DFMRRNG
      INTEGER DFMRBND
      INTEGER DFMIROW
      INTEGER DFMICOL
      INTEGER DFMIRHS
      INTEGER DFMIRNG
      INTEGER DFMIBND
      INTEGER DFMNROW
      INTEGER DFMNCOL
      INTEGER DFMNRHS
      INTEGER DFMNRNG
      INTEGER DFMNBND
      INTEGER DFMLROW
      INTEGER DFMLCOL
      INTEGER DFMLRHS
      INTEGER DFMLRNG
      INTEGER DFMLBND
      INTEGER DFMLVAL
      INTEGER DFMTAB
C
      INTEGER DFSINIT
      INTEGER DFSROW
      INTEGER DFSCOL
C
      INTEGER DFNCMP
C
```

File: WFINC2

Common block used for the WHIZ optimizer

```
C  $Header: /default/includes/RCS/wfinc2,v 1.1 1995/03/14 16:22:45 dln Exp $
C
C     WHIZ.FH
C
C THIS FILE DEFINES A COMMON AREA NAMED WCR AND SUPPLIES THE TYPES FOR
C ALL OF THE VARIABLES IN THE CR USED BY OML OPTIMIZATION.
C IT ALSO SUPPLIES DECLARATIONS FOR THE INTEGER WF... FUNCTIONS.
C
C$INCLUDE WWCPRAG.FH
C     USE _WCR FOR WATCOM
C     COMMON  /_WCR/
C     USE WCR OTHERWISE (E.G., 370)
      COMMON  /WCR/
     *  XNAME, XCORE, XCORELEN,
     *  XACTCASE, XACTFILE, XACTPROB, XBOUND, XCHOBJ, XCHRHS, XCMASK,
     *  XDATA, XINSERT, XLOADB, XMINMAX, XOBJ., XPUNCH, XRANGE, XRHS,
     *  XRMASK, XRNGFILE, XRNGPRNT, XSAVEB, XSOLFILE, XSOLPRNT,
     *  XSOLSTAT, XEPS, XFUNCT, XINTGOAL, XMAXVAR, XPARAM, XPENCOST,
     *  XPHI, XRSTOP, XSIF, XSSCALE, XTHETA, XTOLCHK,
     *  XTOLCHZR, XTOLCKRW, XTOLCLRT, XTOLDJ, XTOLERR,
     *  XTOLFSTM, XTOLINV, XTOLLMAX, XTOLPERT, XTOLPIV, XTOLREL,
```

```
     *  XTOLRMAX, XTOLRWRT, XTOLUREL, XTOLV, XTOLZE, XZERO,
     *  XCHECKSW, XCLOCKSW, XCOMPERR, XCOMPSW, XCRASHSW,
     *  XCYCLESW, XDEGEND, XDEGMAX, XDEMAND, XDETAIL,
     *  XDOATTN, XDODELTM, XDOFEAS, XDOFREQ1, XDONFS, XDOUNB,
     *  XDUAL, XEQUIL, XFEAS, XFREQINV, XFREQLOG, XFREQSAV,
     *  XFREQSUM, XINVERT, XITERNO, XJ, XLUDENSE,
     *  XLUFILL, XLUINV, XM, XMAJERR,
     *  XMAXITER, XMAXPASS, XMAXTIME, XMINERR, XNEGDJ,
     *  XNIF, XNOWT, XRUNMODE, XRYANOSB, XSCALESW, XSCRNSW,
     *  XSLPNZ, XTIMESAV, XTRACE, XTRAN, XUNBDNDX, XUSEFREE
C
      CHARACTER*8 XNAME
      INTEGER     XCORE
      INTEGER     XCORELEN
C
      CHARACTER*8 XACTCASE
      CHARACTER*8 XACTFILE
      CHARACTER*8 XACTPROB
      CHARACTER*8 XBOUND
      CHARACTER*8 XCHOBJ
      CHARACTER*8 XCHRHS
      CHARACTER*8 XCMASK
      CHARACTER*8 XDATA
      CHARACTER*8 XINSERT
      CHARACTER*8 XLOADB
      CHARACTER*8 XMINMAX
      CHARACTER*8 XOBJ
      CHARACTER*8 XPUNCH
      CHARACTER*8 XRANGE
      CHARACTER*8 XRHS
      CHARACTER*8 XRMASK
      CHARACTER*8 XRNGFILE
      CHARACTER*8 XRNGPRNT
      CHARACTER*8 XSAVEB
      CHARACTER*8 XSOLFILE
      CHARACTER*8 XSOLPRNT
      CHARACTER*8 XSOLSTAT
      REAL*8      XEPS
      REAL*8      XFUNCT
      REAL*8      XINTGOAL
      REAL*8      XMAXVAR
      REAL*8      XPARAM
      REAL*8      XPENCOST
      REAL*8      XPHI
      REAL*8      XRSTOP
      REAL*8      XSIF
      REAL*8      XSSCALE
      REAL*8      XTHETA
      REAL*8      XTOLCHK
      REAL*8      XTOLCHZR
      REAL*8      XTOLCKRW
      REAL*8      XTOLCLRT
      REAL*8      XTOLDJ
      REAL*8      XTOLERR
      REAL*8      XTOLFSTM
      REAL*8      XTOLINV
      REAL*8      XTOLLMAX
      REAL*8      XTOLPERT
      REAL*8      XTOLPIV
```

```
      REAL*8     XTOLREL
      REAL*8     XTOLRMAX
      REAL*8     XTOLRWRT
      REAL*8     XTOLUREL
      REAL*8     XTOLV
      REAL*8     XTOLZE
      REAL*8     XZERO
      INTEGER    XCHECKSW
      INTEGER    XCLOCKSW
      INTEGER    XCOMPERR
      INTEGER    XCOMPSW
      INTEGER    XCRASHSW
      INTEGER    XCYCLESW
      INTEGER    XDEGEND
      INTEGER    XDEGMAX
      INTEGER    XDEMAND
      INTEGER    XDETAIL
      INTEGER    XDOATTN
      INTEGER    XDODELTM
      INTEGER    XDOFEAS
      INTEGER    XDOFREQ1
      INTEGER    XDONFS
      INTEGER    XDOUNB
      INTEGER    XDUAL
      INTEGER    XEQUIL
      INTEGER    XFEAS
      INTEGER    XFREQINV
      INTEGER    XFREQLOG
      INTEGER    XFREQSAV
      INTEGER    XFREQSUM
      INTEGER    XINVERT
      INTEGER    XITERNO
      INTEGER    XJ
      INTEGER    XLUDENSE
      INTEGER    XLUFILL
      INTEGER    XLUINV
      INTEGER    XM
      INTEGER    XMAJERR
      INTEGER    XMAXITER
      INTEGER    XMAXPASS
      INTEGER    XMAXTIME
      INTEGER    XMINERR
      INTEGER    XNEGDJ
      INTEGER    XNIF
      INTEGER    XNOWT
      INTEGER    XRUNMODE
      INTEGER    XRYANOSB
      INTEGER    XSCALESW
      INTEGER    XSCRNSW
      INTEGER    XSLPNZ
      INTEGER    XTIMESAV
      INTEGER    XTRACE
      INTEGER    XTRAN
      INTEGER    XUNBDNDX
      INTEGER    XUSEFREE
C
      INTEGER    WFINIT
      INTEGER    WFDEF
      INTEGER    WFSET
```

```
      INTEGER   WFMPSIN
      INTEGER   WFMPSOU
      INTEGER   WFLOAD
      INTEGER   WFOPT
      INTEGER   WFEND
C
      INTEGER   WFCVAL
      INTEGER   WFCRHS
      INTEGER   WFCRNG
      INTEGER   WFCBND
C
      INTEGER   WFRVAL
      INTEGER   WFRRHS
      INTEGER   WFRRNG
      INTEGER   WFRBND
C
      INTEGER   WFRNAME
      INTEGER   WFCNAME
      INTEGER   WFRMASK
      INTEGER   WFCMASK
      INTEGER   WFSROW
      INTEGER   WFSCOL
      INTEGER   WFRROW
      INTEGER   WFRCOL
C
      INTEGER   WFRLVAL
      INTEGER   WFRLIST
      INTEGER   WFCLIST
      INTEGER   WFSPRT
      INTEGER   WFSFILE
      INTEGER   WFRCORD
      INTEGER   WFRPRT
      INTEGER   WFRFILE
C
      INTEGER   WFSAVEB
      INTEGER   WFLOADB
      INTEGER   WFPUNCH
      INTEGER   WFINSRT
C
      INTEGER   WFMGDMP
      INTEGER   WFMGLOD
      INTEGER   WFCRGET
      INTEGER   WFCRPUT
C
```

Appendix G-E: ENSYS95 Data Conversion

The current data used in the MRM (and ERM) were updated for the AEO97 using 1995 WORLD model data (referred to as ENSYS95) provided by EnSys Co. Due to the differences in data format (OMNI VS OML) and naming conventions, the ENS95 data had to undergo convertion and new mapping data tables had to be added to the MRM files prior to being used by the MRM.

The following provides a summary of the effort it took to convert the ENSYS95 OMNI tables into OML RTB tables (to be read by the matrix generation code).

1. The code to convert the OMNI tables to RTB tables is found in directory /refine/prj/ensys/source95/... with the following name: omni2rtb.c

2. The ENSYS95 OMNI tables are located in directory /refine/prj/ensys/data95/... with the following names:
   v0.ensrymeq.gdb (only this was used)
   v0.refcap2s.gdb
   v0.sumspec.gdb

3. To compile and execute the omni2rtb type:
   compile: cc -o <exec filename> <source code filename>
   execute: <exec filename> <input data path/filename> <output filename>
   For example, if all files are in the same directory:
   cc -o omniexec omni2rtb.c
   omniexec v0.ensrymeq.gdb omniout

4. ERRORs found in the original v0.ensrymeq.gdb tables (and corrected in the v0.ensrymeq.mod version) include:
   v0.ensrymeq.gdb
   - all references to "Total C5+ YIELD" should be commented using an "* " at the beginning of each line (only one needed fixing)
   - Table ALK -- change "- 500" to " -500"
     Row: [STM] STEAM, LB/BBL
     Col: [C3A]
   - Table HCR -- remove comment to activate the 0.4 in
     Row: [DDL] HYCK DIESEL
     Col: [DIE] & [MLD]
   - Table ALK -- change "-.03" to "-.030"
     Row: [FUL] FUEL, FOE/BBL
     Col: [N5A]

5. Additional information:
   - According to a memo from Will McCullers (5-29-96), an RTB table (T:RCPEIA) was added to allow the continued use of EIA-specific recipes which are necessary to produce petroleum coke in the matrix.

- Additional mapping tables were added to gasoblnd.dat and distblnd.dat files to change naming convention conflicts between the WORLD model and the PMM:

gasoblnd.dat	Z:MAPGSLPD & Z:MAPGSLSP
distblnd.dat	Z:MAPDFOPD & Z:MAPDFOSP

6. Of the tables updated using the ENSYS95 data (listed below), the following additional changes have been made to selected tables:

refproc.dat:

T:FUM -- all FUL coef changed from 1.0 to .999 so that the coef could be changed in memory.

T:OLE -- FUL coef changed from .071 to -.003 for mode PGU; LOS coef changed from -.007 to -.067 for mode PGU; removed comment from NGS stub to connect to mode PGU

T:SUL -- STM coef changed from -877.6 to 590.0 for all modes (update from MAPLES)

T:STG -- FUL,CAP,STM,KWH,OVC coef changed

FUL	-.204	old:-4.93
CAP	1000.	old: 1.0
STM	1000.	old: 1.0
KWH	-3.92	old:-.094
OVC	-.0458	old:-.555

T:SCL -- FUL, OVC coef (.001) removed for mode STG

T:FCC -- FUL,KWH coef changed from 0 to -.012 and -0.4 for (respectively) for modes: A70,A85,B70,B85,C70,C85,D70,D85,E70,E85,F70,F85,G70,G85,H71,H85,I70, I85,J70,785,K70,K85,70A,85A,70B,85B,70C,85C,70D,85D,70E,85E,70F,85F, 80G,85G,71H,85H,70I,85I,70J,85J,70K,85K

T:ETH -- removed modes TAM,THM,TAE,THE; changed coef on modes ETB & MTB:

	DATA	T:ETH
**	ETB	MTB
MTB	0.0000	1.0000
ETB	1.0000	0.0000
ETH	-0.4310	0.0000
MET	0.0000	-0.3410
I4E	-0.6940	-0.7940
HH2	-0.0000	-0.0000
LOS	0.1250	0.1350
OVC	-0.1570	-0.1570
KWH	-2.8100	-2.5500
STM	-384.0	-384.00
CAP	1.0	1.0

*

T:ETM -- new table added:

	DATA	T:ETM		
**	TAE	TAM	THE	THM
TAE	1.0000	0.0000	0.0000	0.0000
THE	0.0000	0.0000	1.0000	0.0000
ETH	-0.3820	0.0000	-0.3430	0.0000
MET	0.0000	-0.3030	0.0000	-0.2690

R5E	-0.6940	-0.8770	0.0000	0.0000
R6E	0.0000	0.0000	-0.6980	-0.8210
TAM	0.0000	1.0000	0.0000	0.0000
THM	0.0000	0.0000	0.0000	1.0000
HH2	-0.0078	-0.0078	-0.0078	-0.0078
LOS	0.0838	0.1878	0.0488	0.0978
OVC	-0.1730	-0.1730	-0.1900	-0.1900
KWH	-6.3500	-6.0900	-6.3500	-6.0900
STM	-1060.0	-1062.0	-1062.0	-1062.0
CAP	1.0	1.0	1.0	1.0
ETM	1.0		1.0	

gasoblnd.dat:

-Added SSE Spec for Splash Blending TRG: T:GSSE, T:ESSE, T:CSSE, T:WSSE, T:MSSE

-Added stub SSE to T:GSLUTI with coef of 0.2

mchproc.dat:

-added ETB mode to ETX at merchant plant;

-added transfer connect of ETH from RF to MP;

-added transfer connect of ETB from MP to RF.

7. The following list of *.dat and tables were updated using the new ensys95 data:

distblnd.dat:	DATA	T:DCC
	DATA	T:DCB
gasoblnd.dat:	DATA	T:MCO
	DATA	T:UNCBV
	DATA	T:RFMBV
	DATA	T:GCB
	DATA	T:GCC
recipes.dat:	DATA	T:RCP
refproc.dat:	DATA	T:MATBAL
	DATA	T:HLO
	DATA	T:RST
	DATA	T:SDA
	DATA	T:KRD
	DATA	T:KRF
	DATA	T:VBR
	DATA	T:NDS
	DATA	T:DDS
	DATA	T:FDS
	DATA	T:RDS
	DATA	T:RFH
	DATA	T:RFL
	DATA	T:RFC
	DATA	T:SPL
	DATA	T:HCN

```
                DATA    T:OLE
                DATA    T:DHT
                DATA    T:JFP
                DATA    T:FCC
                DATA    T:FGS
                DATA    T:TCG
                DATA    T:TCN
                DATA    T:TCV
                DATA    T:HCR
                DATA    T:HCV
                DATA    T:ETS
                DATA    T:C24
                DATA    T:H56
                DATA    T:C4T
                DATA    T:FEX
                DATA    T:HDN
                DATA    T:JPS
                DATA    T:DEW
                DATA    T:ALK
                DATA    T:CPL
                DATA    T:DIP
                DATA    T:ETH
                DATA    T:CYC
                DATA    T:ALM
                DATA    T:DIM
                DATA    T:ARP
                DATA    T:RES
                DATA    T:LUB
                DATA    T:PHI
                DATA    T:TRI
                DATA    T:C4I
                DATA    T:C4S
                DATA    T:H2P
                DATA    T:H2X
                DATA    T:SUL
                DATA    T:VCU
                DATA    T:KWG
                DATA    T:STG
                DATA    T:REL
                DATA    T:PFA
                DATA    T:SCL
                DATA    T:FUM
stream.dat:     DATA    T:TRS
```

Appendix G-F: Refinery Processes

Refinery Process	Abbreviation
Atmospheric crude distillation	ACU
Alkylation	ALK
Alkynax	ALM*
Aromatic recovery	ARP
Polymerization	CPL
Cyclar	CYC
Butane isomerization	C4I
Butane splitter	C4S**
Akylation feed butene isomerizer	C4T*
Butane isomerization	C4X***
C2E to C4E dimerization	C24*
Distillate desulfurizer	DDS
Mid-distillate deep hydrotreater	DHT
Dimersol	DIM
Gas oil dewaxer	DEW
Di-isopropyl ether	DIP*
Etherol	ETH
Cryogenic C2 fractionation	ETS*
Etherrol unit	ETX***
FCC feed hydrofiner	FDS
Fluid cat cracker	FCC
Mid-distillate furfural treating	FEX
Fuel plant	FUM**
Fuel plant	FUX***
Gas oil hydrocraker	HCR
Residum hydrocracker	HCV
Naphta hydrocracker	HCN

Refinery Process	Abbreviation
High density jet fuel hydrotreating	HDN
Hydogen/fuel gas reformer hydrogen	HLO**
H2-stream reformer	H2P
H2-partial oxidizer	H2X
Hydrogeneration normal pentenes/hexenes	H56*
High density jet fuel prefactionation	JFP
Recut for JTA	JPS**
Delayed-coker	KRD
Fluid/flexi-coker	KRF
Power generation	KWG**
Lub and wax	LUB
Naphta hydrotreater	NDS
C2-C5 dehydrogenation	OLE*
C2-C5 dehydrogenation	OLX***
Pentane/hexane isomerization	PHI
Residuum desulfurizer	RDS
HP semi-regenerative reformer	RFH
LP cyclic reformer	RFL
LP continuous reformer	RFC
Solvent deasphalting	SDA
Sulfur, short tons/day	SUL
Naphta splitter	SPL
Steam generation, lbs/hr	STG**
Steam generation, lbs/hr	STX***
Thermal cracker C2-C4 feed	TCG*
Thermal craker naphta feed	TCN*
Thermal craker gas oil feed	TCV*
Total recycle isomerization	TRI*
Vaccum distillation	VCU
Visbreaker/thermal craker	VBR

* : Processes involved in reformulated gasoline manufacturing
**: Utilities and pseudo-units
***: Processes represented in OXY-Refineries

APPENDIX H

Historical Data Processing

APPENDIX H. Historical Data Processing

H.1 Processing Data for PMM History File

Data Dump Programs:

1) PRJ6007.NEMS.MARKUP.PRICE.HISTFILE: reads markup files and creates &PRJ.PRICES.HIST.SASDB:PBTU9095.

2) PRJ6007.NEMS.READ.SEDS: reads SEDS sectoral consumption data and the total consumption number from the most recent PSA and puts the data into PRJ6007.HISTORY.SASDB:SEDS.

3) Manually update PRJ6007.FUELUSED from fuel consumption data in Table 47. of the PSA.

4) (Manually update PRJ6007.ELCG.FLATFILE.DATA(NGPFUEL) (Chetha).

5) Manually update PRJ6007.ELCG.FLATFILE.DATA(MSPRICE) using estimates from PFPRICES.WK4.

6) PRJ6007.ELCG.FLATFILE.DATA:MBL,CRDWHPR,CRPRODAY (bbl/day) updated by Ted.

7) PRJ6007.COGEN.F867.SASDB:D0629941 updated by cogen program. Updated cogen data was not used for AEO97 because of observed problems with the data.

Data Processing Files:

1) PRJ6007.PMM.PROCESS.PSADATA - loads &prj.ogirs95a.data and &prj.ogirs95b.data(See PSA Query Documentation)which is a dump from OGIRS and saves into &prj.history.sas.psadata.psdata. This part should be commented out after running for the first time each year. The following sections read, transpose, and put required data into SASDB. See attachment for list of missing OGIRS data.

   Input files: PRJ6007.HISTORY.SAS.PSADATA:PSDATA
   Output file: PRJ6007.PMM.HISTORY.SASDB:PSDATA

2) PRJ6007.PROCESS.NGPFUEL - reads natural gas plant fuel data, transposes and puts in SASDB

   Input files: PRJ6007.PMM.ELCG.FLATFILE.DATA(NGPFUEL) manually updated by Bruce

Output file: PRJ6007.FUELUSE.HIST.SASDB:NGPFUEL includes PADD Year Volume

3) PRJ6007.PMM.PROCESS.RFFUEL - reads refinery fuel consumption data, puts in SASDB

Input files: PRJ6007.FUELUSED manually updated
and PRJ6007.MISCELL.SASDB:BTU1

Output file: PRJ6007.PMM.FUELUSE.HIST.SASDB:RFFUELCD in BTU's

4) PRJ6007.PMM.PROCESS.CRUDE1 - reads wellhead prices by OGSM region

PRJ6007.PMM.PROCESS.CRUDE2 - reads conventional and conventional/EOR production by OGSM region

Input files: PRJ6007.ELCG.FLATFILE.DATA(CRDPRODAY)
(CRDWHPR)
Output file: PRJ6007.PRODTN.HIST.SASDB:CRDOGSM
PRJ6007.PRICES.HIST.SASDB:CRDPRIC

5) PRJ6007.PMM.PROCESS.COGEN - reads cogen, capacity, and fuel use by Census Division. Transposes for regional headings and puts in SASDB

Input files: PRJ6007.COGEN.F867.SASDB.D0629941

Output file: PRJ6007.PMM.HISTORY.DATA.SASDB:COGEN

6) PRJ6007.PMM.PROCESS.PRCDATA - reads prices and petrochemical prices, transposes for regional headings and puts in SASDB. Data set "test1" must be updated for current year for CD4 and CD8.

Input files: PRJ6007.PRICES.HIST.SASDB:PBTU9095
PRJ6007.ELCG.FLATFILE.DATA(MSPRICE)

Output file: PRJ6007.PRICES.HIST.SASDB:PRDPRIC

7) PRJ6007.PMM.PROCESS.DEMAND - reads sectoral demand from SEDS, estimates most recent year's sectoral demand by using current PSA total demand times the sector ratios. Type in PSA total product supplied number from Table 3.

Input files: PRJ6007.HISTORY.SASDB:SEDS

Output File: PRJ6007.PRODTN.HIST.SASDB:DEMAND

8) PRJ6007.PMM.PROCESS.MISCELL - includes data for miscellaneous inputs, to be manually updated each year.

Output file: PRJ6007.PMM.MISCELL.SASDB:MISCELL

Creating PMM Flatfile:

9) PRJ6007.PMM.MAKE.HIST.FLATFILE - reads SASDBs and puts them in flatfile

Input files: PRJ6007.PMM.HISTORY.DATA.SASDB:PSDATA
PRJ6007.FUELUSE.HIST.SASDB:NGPFUEL
PRJ6007.FUELUSE.HIST.SASDB:RFFUELCD
PRJ6007.PRODTN.HIST.SASDB:CRDOGSM
PRJ6007.PRODTN.HIST.SASDB:DEMAND
PRJ6007.PRICES.HIST.SASDB:CRDPRIC
PRJ6007.PMM.HISTORY.DATA.SASDB:COGEN
PRJ6007.PRICES.HIST.SASDB:PRDPRIC
PRJ6007.PMM.MISCELL.SASDB:MISCELL

Output file: PRJ6007.RFHIST6

** lrecl=100

Petrochemical Feedstocks

from SEPER APPENDIX

p naptha= 1.23* WOP
other = 1.607 * WOP

use 92 prices and volumes for weighted average pf price.

pfprices.wk4

PSA Query Instructions:

Copy p:\fs-f1\6019\ogdata\ps\access.dbf and data.dbf to d:\prj\ogirs

In Access:

Open database c:\ogirs\getpsa.mdb
click on macro
run delete_and_append_records2

This will recreate tables:text_to_value1 and text_to_value2 (by deletingvalues and appending new data) and print them out to Excel spreadsheets:sasinpt1.xls and sasinpt2.xls

In Excel:

Open each file and do File Output To, space delimited text file

In FTP/TCP:

Transfer files to mainframe

On Mainframe:

rename and resave files as card
sasinpt1.txt=&prj.ogirs95a.data
sasinpt2.txt=&prj.ogirs95b.data
Note:tables could not be saved as correctly as text by Access or Lotus.

H.2 Processing Data for STEO Years

The *Short-Term Energy Outlook* (STEO) published by the Energy Information Administration provides quarterly projections two years into the future. Since the STEO is EIA's official forecast during this period, the Petroleum Market Model was set up to produce numbers that very closely match the STEO when a switch in the PMM is turned on. The information in this section describes the programs that are used to generate this data for the PMM. The data is then added to the input file that contains the history data described in Section H.1.

The files below are on mainframe account 6007, PRJ, unless otherwise stated. Input data are read from and output data are written to

&PRJ6007.NEMSSTEO.COMP.SASDB

unless otherwise indicated. Files 1 and 2 only need to be updated once a year when new historical price and supply data are available. The other files can be updated with data from any STEO projection. Note that some files produce output for other files, so the order of execution is important. For example, program 5 inputs data from programs 2 and 4.

Beginning with AEO97, the Petroleum Market Model was configured to produce numbers that very closely match STEO for the high and low world oil price scenarios as well as the reference case. The data processing programs affected by this change have been updated into three versions which are run independently to produce data for the appropriate scenario. The programs were renamed with an additional extension to denote the reference (.BASE), high world oil price (.HIGH), and low world oil price (.LOW) cases.

1. NEMS.HIST.PRICES.MARGINS

This file creates a data file “RETMARG” which contains historical product prices, crude prices, and margins.

Output file: RETMARG in PRJ6007.A.SASDB

2. NEMSSTEO.HISTMARG

This file calculates differentials that are used to estimated regional prices from U.S. average STEO prices. Differentials are also calculated from crude oil prices for those fuels that STEO does not price.

Input file: RETMARG from PRJ6007.A.SASDB

Output files: RCSPRD88

CDSPRD88
RFSPRD88

3. NEMSSTEO.HISTFACT

This file calculates factors from petroleum supply data which are used to apportion U.S. data to the PADD level.

Output file: SUPPFACT

4. NEMSSTEO.PRICE.DATA

STEO prices are typed in to this program and the differentials from file 1 are input, then regional PMM product prices are estimated.

Input files: CDSPRD88
RCSPRD88
RFSPRD88
Output files: PRICES
RRAC87

5. NEMSSTEO.READ.STEODB.OTHINP

This program reads in data from the STEO database and outputs data needed for later processing.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)

Output files: CAPUTIL (STEO capacity and utilization rates)
OTHIMP (imports of unfinished oils, ethers, and gasoline blending components)
OTHINPUT (other input data)

6. NEMSSTEO.SUPPLY.PUBDATA.BASE
.HIGH
.LOW

In this file, supply data are typed in from the STEO publication.

Input files: SUPPFACT
OTHIMP
CAPUTIL

Output files: USSUP (A version of each of these files is created for each scenario.)
CRUDEINP
CRDPROD
PADSUP

7. NEMSSTEO.READ.STEODB.PRODSUP

This program uses data from the STEO database and file 5, and develops product supplied data for the PMM.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)
USSUP

Output files: PRODSUP
PRODSECT

8. NEMSSTEO.READ.STEODB.REFPROD

This program uses data from the STEO database and file 2, and develops refinery production numbers.

Input files: ALLBBB (from &PRJ6489.STIFSIII.monyy.SASDATA)
SUPPFACT
Output: REFPROD

9. NEMSSTEO.RFFUEL

This program estimates refinery fuel consumption based on historical values and STEO crude input estimates.

Input: CRUDEINP
RFFUELCD (from &PRJ6007.FUELUSE.HIST.SASDB)
Output: FUELUSE

10. NEMSSTEO.WELLPR.BASE
.HIGH
.LOW

This file estimates regional crude wellhead prices based on wellhead price equations in the PMM provided by the Oil and Gas Supply Team and STEO's world oil price projections.

Input: RRAC87
Output: WELLREG (A version of this file is created for each scenario.)

11. NEMSSTEO.ALLDATA.BASE
.HIGH
.LOW

This program reads in all the relevant data created by the previous programs, drops the last historical year,[1] and writes out the data needed to input into the PMM history file.

Input:	Output:
PADSUP	SPADSUP
REFPRD	SREFPRD
USSUP	SUSSUP
OTHINPUT	SOTHINP
PRODSUP	SPRODSUP
PRODSECT	SPRDSECT
FUELUSE	SFUELUSE
PRICES	SPRICES
WELLREG	SWELLREG
CRDPROD	SCRDPROD

The appropriate versions of the input files must be used with the corresponding version of file 10. For example, the file USSUP created from NEMSSTEO.SUPPLY.PUBDATA.BASE should be used as input to NEMSSTEO.ALLDATA.BASE, whereas the file USSUP created from NEMSSTEO.SUPPLY.PUBDATA.HIGH should be used as input to NEMSSTEO.ALLDATA.HIGH.

The output data from file 10 are read in the program
&PRJ6007.PMM.MAKE.HIST.FLATFILE
which produces a file containing PMM output data for the history and STEO years.

12. NEMSSTEO.COGEN.PLANNED

This program adds planned capacity for the STEO years to existing capacity and writes to a file which is read into the program that creates the PMM history file.

[1]The last historical year was included to provide a check that the estimates for the forecast years were reasonable.

Input files:	PLANCAP	from JDI6007.COGEN.F867.PLAN9596.SASDB, where 9596 represent the years with planned capacities
	COGEN96	from PRJ6007.PMM.HISTORY.DATA.SASDB
Output file:	COGENP97	to PRJ6007.PMM.HISTORY.DATA.SASDB

H.3 Processing Other Historical Data

In addition to developing an input history file (described in Appendix H-1), the PMM team utilizes other historical data to develop some inputs and to support analysis of the model results. This section describes the updating of these data, which is usually done on an annual basis.

Crude Oil Price Data

EIA-14: Crude oil prices are used to calculate historical margins which are used to analyze the margins estimated in the model. The series used is the refiner acquisition cost (RAC) of imported crude oil which comes from Form EIA-14. The domestic and composite series are also maintained but the imported RAC is the series used in the margin calculations.

The file to update the crude prices each year is:

PRJ6007.EIA14.READyy.FROZEN where yy represents the year

Input files: PRJ6105.ANNUAL.FROZEN.Dyymm where yymm represents year and month

Output files: (all located in PRJ6007.A.SASDB)

YMCRyy	monthly prices for year yy
QTCRyy	quarterly prices for year yy
YRCRyy	annual prices for year yy
YMCRUDE	monthly prices from 1974 through year yy
QTCRUDE	quarterly prices from 1978 through year yy
YRCRUDE	annual prices from 1978 through year yy

A new file must be created each year, changing the yy's of the previous year to the current year.

EIA-856: The EIA-856 survey data are used for analyzing results from the PMM. The EIA-856 collects prices by crude stream for imported crude oil. Differentials between these prices and the world oil price (the refiner acquisition cost of imported oil from the EIA-14) can be calculated and compared with model results. The crude streams can also be segregated by PADD regions and the aggregate crude types found in the PMM. The primary file for reading the EIA-856 data and performing various calculations is

PRJ6007.EIA856.READ95.PORT

Petroleum Product Price Data

Data on petroleum product prices is obtained from the EIA-782 surveys. The EIA-782A survey contains only refiner data, the EIA-782B survey includes petroleum marketers. Prices are produced monthly and updated for an annual publication. One file reads the monthly data, and a second file is set up to read the numbers from the annual data. The file names are as follows:

PRJ6007.A.IMP94.ADF	reads monthly data for 1994
PRJ6007.A.IMP94ANN.ADF	reads annual data for 1994

New files should be created each year with the year indicated in the file name.

Input files: PRJ6015.E782P.R.DATA.ADF.D1994mm.RLSE3 (for final annual update of the monthly data, where mm represent months)
PRJ6015.E782P.R.DATA.ADF.D1994mm.RLSE2 (for monthly data where mm represents months)

Output files:

IMP95A	contains refiner data only
IMP95B	contains refiner and marketer data combined

(these files are found in PRJ6007.A.SASDB.STATE.AByyyy, where yyyy represents two consecutive years (i.e., two years of data are placed in one sasdb, then a new sasdb is created for the next two years, and so on.))

Historical Prices and Margins

Historical wholesale and end-use prices from the EIA-782 are aggregated and presented in tabular form by product type and Census division. Differentials with the world oil price (the refiner acquisition cost of imported oil from the EIA-14) are also calculated by product type and Census division and presented in tabular form for analyzing similar margin calculations from the PMM. The following program has been written to perform these calculations and develop the tables.

PRJ6007.NEMS.HIST.PRICES.MARGINS

Summary

Once the monthly prices from the EIA-782 are finalized for a particular year, set up and run the program A.IMPyy.ADF for that year (yy is the year). Set up and run the EIA14.READyy.FROZEN for that year. Then set up and run NEMS.HIST.PRICES.MARGINS to get the price and margin tables. Update with the annual data as it becomes available (set up and run A.IMPyyANN.ADF for the EIA-782 annual data). Run EIA856.READ95.PORT as needed for analytical purposes.

APPENDIX I

Biofuels Supply Submodule

Appendix I. Biofuels Supply Submodule

I.1 Model Purpose

The objective of the Biofuels Supply Submodule (BSS) is to provide the NEMS Petroleum Market Module (PMM) with supply curves for corn-derived ethanol, thus allowing the PMM to forecast transportation ethanol demand through the year 2015. A secondary objective is to report the energy content of ethanol produced for transportation fuel. The BSS was formerly a submodule of the Renewable Fuels Model but is now a subroutine of the PMM.

To be consistent with the market clearing mechanism adopted for NEMS, the BSS provides ethanol prices in the form of annual price-quantity curves. The curves, derived from an ethanol production cost function, represent the prices of ethanol at which associated quantities of transportation ethanol are expected to be available to refineries for blending with gasoline.

I.2 Relationship of the Biofuels Submodule to Other Models

The BSS's major NEMS linkages are with the Petroleum Market Module and the Coal Market Module (CMM). There is a two-way exchange of information between the BSS and PMM: the PMM provides the BSS with regional diesel fuel prices, while the BSS provides the PMM with delivered ethanol prices. The CMM serves as a source of energy price information for determining the total cost of converting corn into ethanol.

The delivered ethanol prices are provided to the PMM in the form of two supply curves, one for the East North Central Census Division (NEMS region 3), and one for the West North Central Census Division (NEMS region 4).[1] These two Census divisions constitute the major ethanol producing regions in the United States, and are the only two Census divisions considered for ethanol production forecasts.

To determine the delivered ethanol price, the contribution of the net cost of corn feedstock production must be factored in to the total unit price of ethanol. Diesel fuel prices, in dollars per gallon, are also considered as one of two energy cost variable inputs to the ethanol cost projected by the BSS. The other energy price input to the BSS's ethanol production cost function is the price of energy for corn feedstock processing and ethanol conversion. Coal prices are used as a proxy for industrial energy costs. Regional forecasts of energy prices (dollars per million Btu) to industrial consumers are supplied by the CMM.

[1]All regional data inputs to the BSS ethanol production cost function are by Petroleum Administration for Defense Districts (PADDs). The calculated ethanol prices and quantities are mapped to the two Census divisions prior to being written to the NEMS price/quantity COMMON blocks.

Inputs from other NEMS modules are summarized as follows:

- Regional delivered price of diesel fuel to the agricultural/transportation sector. This is obtained from the Petroleum Market Module, and is used for computation of corn feedstock prices.

- Regional delivered price of process energy to industrial consumers, obtained from the Coal Market Module, are used to compute the conversion costs in the regional ethanol supply curves.

- Yield on AA utility bonds. This is obtained from the Macroeconomic Activity Module, and is used for calculating the capital cost factor.

A major source of data supplied to the BSS comes from runs of a model external to the NEMS environment. This model, the Agricultural Resources Interregional Modeling System (ARIMS), was the source of the corn feedstock cost-supply relationships used in the BSS's ethanol cost function. ARIMS was developed at the U.S. Department of Agriculture in the 1980's. The ARIMS is a linear programming resource allocation model that was restructured to account for the value of the by-products produced in the corn-to-ethanol conversion process and to project the net cost of corn feedstocks.[2] In other words, the projected by-product values were credited against the price of corn. The variability of the market price for the feedstock corn and the conversion by-products and the variable influences of competitive uses for corn (e.g., for producing corn syrup) gives rise to broad fluctuations in net corn feedstock prices. All of these factors are considered in the ARIMS model.

ARIMS was run for 1995, 2005, and 2015 to provide price-quantity data for ethanol feedstocks. The changes in the competitive agricultural infrastructure modeled by ARIMS typically occur so slowly that the three years of model projections were deemed sufficient to bracket the behavior within the forecast horizon.[3] Interpolation was used to derive data points for the remaining forecast years. ARIMS is not integrated with NEMS, so that sensitivity analysis between NEMS and ARIMS is not currently feasible.

[2]The net contribution of the cost of corn feedstocks to the price of ethanol is reduced over time by gradually improving conversion process yields. it is also affected by variations in the energy costs for producing corn. PDIESEL, the price of diesel fuel, was the proxy variable used to model the sensitivity of corn production costs to variable energy costs. Analyses were performed off-site and summary statistics are not currently available.

[3]Energy Information Administration, "Component Design Report for Biofuels (Ethanol) Supply Submodule - Renewable Fuels Model - National Energy Modeling System, Draft 7/2/92.

I.3 Modeling Rationale

Theoretical Approach

The BSS uses a process costing approach to model the impacts of net feedstock production costs plus the capital, operating, and process energy costs associated with converting the corn feedstocks to ethanol. In other words, each of the above factors contributes a part of the total price of ethanol projected by the BSS.

As mentioned above, the ARIMS supplied the data for the feedstock cost function variables. Since ethanol feedstock supply curves are a function of many factors (i.e., time, geographic location, demands for traditional agricultural commodities (domestic and foreign, crop and livestock), agricultural production technology, and land availability), the BSS needed the capability to relate such factors in a summary fashion to feedstock resource requirements under competitive agricultural market conditions. The ARIMS provides that capability with the use of a general equilibrium modeling framework.

The ARIMS was used to project corn crop demand and production resources and technology. Subject to constraints that were intended to capture the most important attributes of the agricultural market, the ARIMS model minimized the net cost of producing the specified quantities of corn produced as feedstock for ethanol, and the use of the feed by-products. The crop feedstock demand for ethanol production was set at various levels, with all other aspects of the model held constant. This allowed the linear program to develop sets of points that were used to estimate the step function feedstock supply curve.

Note that with this theoretical approach, only the agricultural, or feedstock production costs are modeled as a function of the total quantity of ethanol produced. The conversion plant process costs, (capital, operating, and process energy) are modeled as process cost which are independent of production quantities. The feedstock production cost components are estimated statistically, whereas the conversion process costs are determined from engineering concepts and data. Actual ethanol conversion process data are, for the most part, proprietary.

I.4 Fundamental Assumptions

Ethanol Production Capacity

An important modeling consideration is the imposition of a constraint on the amount of ethanol production capacity that can be added in any one year. Such a constraint would theoretically prevent unrealistically large increases in production capacity from occurring suddenly in response to potential structural market changes. On the other hand, our research determined that such capital expansion considerations are unnecessary for this modeling application because the lead time for capital expansion is very short and because the feedstock

availability represents the major constraint to the expansion of ethanol production facilities.

No structural changes to feedstock markets are assumed to occur during the forecast horizon. It is assumed that production capacity is utilized fully to meet refinery ethanol demand, and that there is sufficient ethanol production to meet refinery ethanol demand requirements.

Ethanol Production Costs

The ethanol supply-price curve reflects offsetting influences stemming from the effects of increased corn production and improvements in corn-to-ethanol conversion technologies. Net feedstock prices are projected to increase as production increases due to two primary reasons. First, land becomes scarcer, causing both land and feedstock costs to increase, and second, feed by-products become less valuable as larger feedstock quantities are produced. Over time, however, the technologies for growing corn and converting it to ethanol are projected to improve, resulting in downward pressure on ethanol production prices. The BSS models the net effect of all of these factors.

In addition to feedstock prices and quantities derived from ARIMS, the BSS requires feedstock conversion and energy cost data. The conversion cost data were derived from the U.S. Department of Agriculture Report 585 *Ethanol: Economic and Policy Tradeoffs*, and the analytical judgment of Dr. Anthony Turhollow. These costs were developed for the two Census Divisions (3 and 4) that comprise PADD region 2. Although the BSS has the ability to include ethanol production subsidies, they were set at zero for AEO97. The ethanol blender's excise tax credit, which is currently $0.054 per gallon of gasohol (10 percent ethanol, 90 percent gasoline), is modeled in the PMM.

Quantities of energy needed to convert corn to ethanol are assumed to be a positive linear function of input values for years 1, 16, and 26, and to remain constant, at the year 26 value, for years 27, 28, and 29. (The AEO97 runs utilized cost data only up to year 20). Current facilities use 50,000 Btu per gallon of ethanol produced; while state-of-the-art plants run as low as 40,000 Btu per gallon. These two values are used as input values for years 1 and 16, respectively, with later years based on a linear trend of the first two values. This linear interpolation procedure was based on the assumption that, over time, ethanol facilities have become more energy efficient, and will continue to do so as they convert corn to ethanol at higher conversion rates and adopt technology improvements such as organisms with higher tolerances for sugars and ethanol, and molecular sieves to separate water from products. The feedstock conversion energy prices used to develop the feedstock cost function are national prices. Regional prices were not necessary since the relationship between feedstock production costs and energy prices is thought to be relatively constant across regions.

Operating costs for feedstock conversion are also assumed to be a positive linear function of input values for years 1 and 16, but remain constant at the year 16 value for the remaining forecast years. The first-year 1990 value of $0.30 per gallon is an average plant cost for 1987, while the year 16 value of $0.27 per gallon is a projected state-of-the-art plant cost.

Treatment of Energy Crop Ethanol Feedstocks

Significant production of energy crops (e.g., grasses and short rotation trees) for ethanol production is not expected until about 2005. The conversion technology is at a stage wherein demonstration facilities for this technology are not expected to be operational until 1999, at the earliest. A few years of operating experience with the demonstration facilities will be required, and constructing the conversion facilities will also require several years time. Therefore, developing their supply functions for inclusion in the BSS will be deferred until a later AEO.

I.5 Alternative Approaches

Prior to the BSS, the EIA had no in-house modeling system for forecasting alcohol fuel production and demand. The ethanol forecasts for previous *AEO* reports were consensus forecasts prepared by Oak Ridge National Laboratory (ORNL), based on the inter-laboratory renewable fuels energy white paper prepared in 1990. Subsequent to the *AEO92*, a prototype modeling system, utilizing other existing models and a simple supply representation for the production of ethanol, was developed by ORNL. The prototype model consisted of a supply component, a demand component, and a market-clearing process.[4]

For the demand component, an existing model, the Alternative Motor Fuel Use Model (AMFU) was adopted. AMFU is a model used to forecast fuel usage, vehicle usage, and vehicle stock for up to a 40-year horizon. It has the characteristics of both an accounting model for vehicle stocks, and an econometric model with economic activity and prices of fuels for forecasting total fuel demand. The fuel use portion of AMFU assumes that vehicle usage is a function of fuel cost and economic growth, as estimated by statistical models. The proportion of vehicles using any particular fuel (i.e., gasoline, diesel fuel, ethanol) is represented by an algebraic system that includes the relative prices of alternative fuels.

The supply component of the prototype model was represented by a step-function supply curve. The energy crops alternative was represented as a flat supply curve. The sources of these supply functions were Abt Associates (1991) and Tyson (1990), respectively.

Finally, a market-clearing process was used to find an equilibrium solution. The demand model was run for the lowest available price (as determined by the supply curve) of ethanol. If the demand for ethanol exceeded the available supply at that price, the next step of the supply curve was tried. When demand met the available supply, the solution was complete.

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[4]Lee, R., S.M. Cohn, and R.D. Perlack. 1991. *Prototype of an Integrated Model for Projecting Biofuels Consumption*. Draft report prepared for Energy Information Administration, U.S. Department of Energy. Oak Ridge National Laboratory, Oak Ridge, TN.

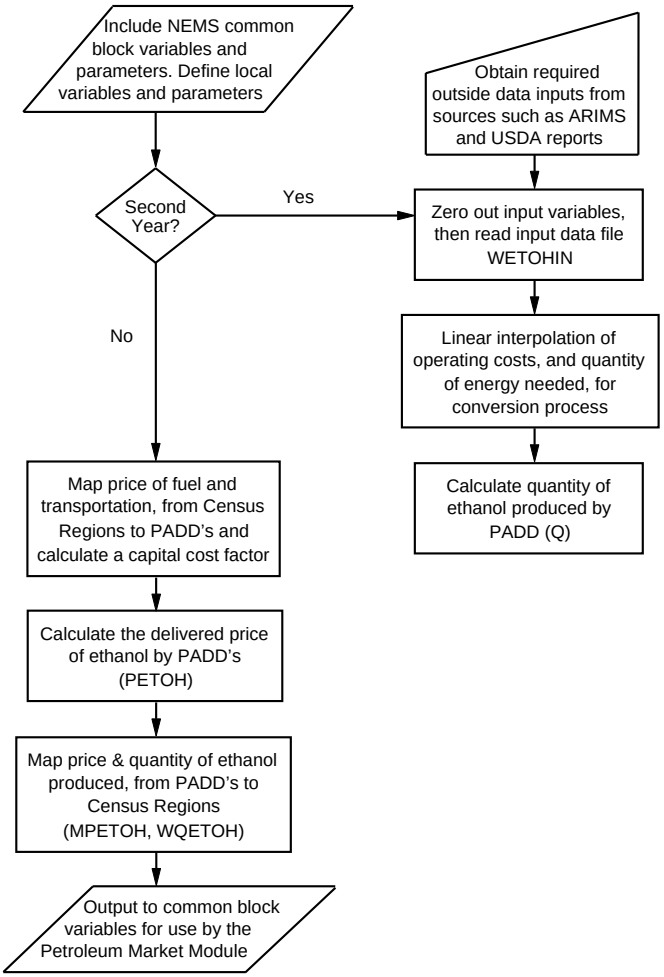
Unlike the prototype, the BSS analyzes supply factors only. Market penetration of alternative-fueled vehicles will be determined in the Transportation Demand Module, and the quantities of ethanol blended with gasoline will be determined by the Petroleum Market Module. No quantitative models for forecasting the production or consumption of ethanol have been identified for application in the BSS.

I.6 Biofuels Submodule Structure

Submodule Flow Diagram

A flow diagram showing the main computational steps and relationships of the Biofuels Supply Submodule is shown in Figure 4. A listing of the NEMS common block variables referred to in Figure 4 can be found in Appendix A.

Figure 4. Biofuels Supply Submodule Flowchart



Key Computations and Equations

The main computations performed by the BSS involve the derivation of a single ethanol supply-price curve. The computations consist of three major steps:

1. Reading in ethanol supply and component cost data, and performing annual interpolations of data values provided on a multi-year basis,

2. Computation of ethanol supply curve (price/quantity) coordinates.

3. Derivation of delivered ethanol prices, calculated as a function of the supply curve coordinates from step 2.

Each of these steps is described below.

After reading in the single input data file, (WETOHIN), the BSS performs a simple linear interpolation on two of the input data variables. These two variables, indexed in Table I-1, are *OPCST* (operating cost for feedstock conversion technologies, exclusive of energy) and *QEN* (quantity of energy needed for feedstock conversion). The BSS gets data values for these variables for 3 years, corresponding to years 1, 16, and 26. Linear interpolations are performed to calculate intermediate yearly values.

The next step involves the calculation of feedstock costs as a function of quantity and year. Readers should recognize this as a standard interpolation routine (Equation I-1) supplied to the data in Table 3. The input data file supplies historical data on costs, as well as ARIMS forecasts, at selected quantities of ethanol production.[5] Because significant ethanol production is currently limited to PADD 2 (Census divisions 3 and 4), the BSS calculates ethanol supply quantities and prices only for Petroleum Administration for Defense District (PADD) 2; supply quantities and prices for the other four PADDs are fixed at zero. The input file therefore supplies the skeleton, for selected years, of the corn production costs $COST_{p,t,e}$ at diesel price p, year t and production volume e. The input file also supplies the diesel price vector D_p and the vector Q_e that contains the quantities for each of the volume steps. Table 3 shows a the skeleton matrix of the BSS. The model interpolates values for the $COST_{p,t,e}$ matrix for years t not given in the input file, and fills in the same cost at all diesel price points in the historical years.

[5]All ethanol produced is assumed to be delivered to refineries.

Table 3. Corn Production Cost Skeleton Matrix ($/gal)

		Production Quantity Points (Billion gallons)					
Year	Diesel Price ($/MMBtu)	0	2.5	5	7.5	10	20
1995	6	0.214	0.315	0.346			
1995	8	0.233	0.336	0.372			
1995	10	0.250	0.359	0.402			
1995	12	0.272	0.378	0.425			
1995	14	0.279	0.408	0.454			
2005	6	0.266	0.301	0.331	0.371	0.420	
2005	8	0.279	0.327	0.347	0.383	0.435	
2005	10	0.306	0.379	0.379	0.407	0.466	
2005	12	0.333	0.394	0.412	0.431	0.488	
2005	14	0.351	0.415	0.436	0.470	0.514	
2015	6	0.255	0.281	0.300	0.326	0.351	0.442
2015	8	0.281	0.296	0.316	0.342	0.367	0.465
2015	10	0.307	0.327	0.349	0.374	0.400	0.511

After the skeleton matrix $COST_{p,t,e}$ has been filled in for all years, a supply curve for a given diesel price $PDIESEL_{pr,t}$ is interpolated from the matrix using the formula:

$$FC_{pr,t,e} = COST_{p-1,t,e} + \frac{PDIESEL_{pr,t} - D_{p-1}}{D_p - D_{p-1}} (COST_{p,t,e} - COST_{p-1,t,e}) \quad \textbf{(I-1)}$$

where:

$FC_{pr,t,e}$ = Cost of producing corn in PADD pr=2 in year t for volume step e ($/gal),

$COST_{p,t,e}$ = Production cost matrix by diesel price step p in year t for volume step e ($/gal),

$PDIESEL_{pr,t}$ = Price of diesel oil in PADD pr=2 in year t ($/MMBtu), and

D_p = Diesel oil price step quantity for each step p ($/MMBtu),

with

$$D_{p-1} < PDIESEL_{pr,t} < D_p.$$

Indices

e	=	point on the supply curve, volume step 1 to 5
f	=	fuel(units in parentheses); 1=gasoline(gallons), 2=diesel(gallons), 3=LPG(gallons), 4=natural gas(MMBtu), 5=electricity(Kwh), 6=coal(MMBtu), 7=fuel for energy crop conversion (MMBtu).
i	=	crop; 1=corn, 2=energy crops
sr	=	Census Region, *sr*=1 to 9
pr	=	PADD, *pr*=1 to 5
t	=	year, 1990 $\leq t \leq$ 2015

The third major computational step involves the derivation of delivered ethanol prices for each PADD. The ethanol prices, *PETOH*, are calculated as a linear function of (1) the corn feedstock cost $FC_{pr,t,e}$ shown above, (2) the price of diesel fuel, which serves as a proxy for all of the energy costs of producing the feedstock and transporting it to the conversion facility, and (3) corn-to-ethanol conversion facility process cost contributions, namely, capital, non-energy-related operating costs, and process energy costs.

The delivered ethanol price equation is as follows:

$$PETOH_{i,pr,t,e} = FC_{pr,t,e} + CAPCST_{i,t} * CCF + OPCST_{i,t} + QEN_{i,t} * PEN_{pr,t} - SUB \quad \text{(I-2)}$$

where:

$PETOH_{i,pr,t,e}$ = Delivered price of ethanol produced from crop *i* in PADD *pr* in year *t* for volume step *e* for quantity of ethanol demand *Q* ($/gal)

Note: Since PETOH is given in $/gallons, the product of B1 * Q is also $/gallons. This is achieved by applying the unit ($10^{-9}$$ year/gal^2) to B1.

$FC_{pr,t,e}$ = Feedstock corn production cost for PADD *PR*=2 in year *t* for volume step *e* ($/gal),

$CAPCST_{i,t}$ = Capital cost for conversion technology for crop *i* in year *t* ($/gal),

CCF = Capital cost factor (dimensionless),

$OPCST_{i,t}$ = Operating costs, exclusive of energy, for crop *i* conversion technology in year *t* ($/gal),

$QEN_{i,t}$ = Quantity of energy needed to convert crop *i* to ethanol in year *t* (MMBtu/gal),

$PEN_{pr,t}$ = Price of energy used in the corn-to-ethanol conversion process in PADD *pr* in year *t* ($/MMBtu),

SUB = Subsidy for ethanol production ($/gal), currently zero

The capital cost factor (CCF) used in equation I-3, which is based on a 8-year amortization period, is calculated as follows:

$$CFF = MC\_RMPUAANS_t * (1 + MC\_RMPUAANS_t)^8 / ((1 + MC\_RMPUAANS_t)^8 - 1) \quad \textbf{(I-3)}$$

where:

$MC\_RMPUAANS$ = yield on AA-grade utility bonds (a Macroeconomic Activity Module output variable).

The quantity of ethanol used as a transportation fuel, $WQETOH_{cr,t,e}$ is derived from the following equation:

$$WQETOH_{(cr \subset 3,4),t,e} = Q_e \cdot PADD2CR_{2,3} \cdot QSRFACT \quad \textbf{(I-4)}$$

where:

$WQETOH$ = Quantity of ethanol used as a transportation fuel, in barrels per day, for Census division 3 and 4, year *t*, and supply step *e*,

Q_e = quantity of ethanol produced from crop *i* in PADD 2 in year *t* for volume step *e* (billion gallons/year),

$PADD2CR_{2,3}$ = Conversion factors to convert from PADD 2 to Census Regions 3 and 4,

$QSRFACT$ = Conversion factor to convert from million gallons per year to thousand barrels per day.

The price of ethanol used as a transportation fuel, $WPETOH_{cr,t,e}$ is derived from the following equation:

$$WPETOH_{(cr=3,4),t,e} = PETOH_{1,pr,t,e} \cdot PADD2CR_{2,3} \cdot PETOHSRFACT \quad \textbf{(I-5)}$$

where:

WPETOH	=	Price of ethanol used as a transportation fuel, in $ per barrel, for Census division 3 and 4, year *t*, and supply step *e*,
$PETOH_e$	=	Price of ethanol produced from corn in PADD 2 in year *t* for volume step *e* ($/gallon),
$PADD2CR_{2,3}$	=	Conversion factors to convert from PADD 2 to Census Regions 3 and 4,
PETOHSRFACT	=	Conversion factor to convert from gallons to barrels

I.7 Inventory of Variables, Data, and Parameters

This section describes the variables, data inputs, and parameter estimates associated with the Biofuels Submodule. Table I-1 provides a tabular listing of model input data and input variable parameters. The table contains columns with information on item definitions, modeling dimensions, data sources, and measurement units. Similarly, Table I-2 provides an indexed listing of model output data and parameters.

Table I-1. NEMS Biofuels (Ethanol) Supply Submodule Inputs

Model Variable	Definition and Dimensions	Source	Units
CAPCST	Capital cost for conversion technology for crop *i* in year *t*	USDA/ERS. 1988. Report #585	$/gallon
COST	Cost of producing corn in PADD 2 at diesel price step *P* in year *t* at volume step *e*	ARIMS Output Trumble. 1994	$/gallon
D	Values of diesel price steps *p*	Trumble. 1994	$/MMBtu
Q	Quantity at each volume step *e*	Trumble. 1994	billion gallons
MC_RMPUAANS	Yield on AA utility bonds for year *t*	Macroeconomic Market Module	Dimensionless
OPCST	Operating costs, exclusive of energy, for conversion technology of crop *i* in year *t*	USDA/ERS. 1988. Report 585	$/gallon
PADD2CR	Conversion rates to convert from PADD *pr* to Census Region *sr*	A. Turhollow	Dimensionless
PDSTR	Price of diesel for transportation in Census Region *sr* in year *t*	Petroleum Market Module	$/gallon
PCLIN	Price of coal for industrial use in Census Region *sr* in year *t*	Coal Market Module	$/MMBtu
QEN	Quantity of energy needed to convert crop *i* to ethanol in year *t*	Marland & Turhollow. 1991	MMBtu/gallon
QFUEL	Quantity of fuel type *f* used in the production of crop *i* in year *t*	Marland & Turhollow. 1991	Gallons for f=1,2,3 MMBtu for f=4 kWh for f=5

Table I-2. NEMS Biofuels (Ethanol) Supply Submodule Outputs

Model Variable	Definition and Dimensions	Source	Units
CCF	Capital cost factor	Accounting Parameter	Dimensionless
HEATCONT	Heat content of ethanol	Value set to 3.5448	MMBtu/Bbl
PDIESEL	Price of diesel to industrial users in PADD *pr* in year *t*	Mapped from *PDSTR*	$/gallon
PEN	Price of energy used in the corn to ethanol conversion process in PADD *pr* in year *t*	Mapped from *PNGIN*	$/MMBtu
PETOH	Delivered price of ethanol produced from crop *i* in PADD *pr* in year *t* for volume step *e* for quantity of ethanol demand *Q*	Endogenous Variable	$/gallon
PETOHSRFACT	Conversion factor to convert prices from $/gallon to $/barrel	42 gallons equals one barrel	Gallons/barrel
Q	Delivered quantity of ethanol produced from crop *i* in PADD *pr* in year *t* for volume step *e* for price of ethanol *PETOH*	Endogenous Variable	Billion gallons/year
QSRFACT	Conversion factor to convert from million gallons per year to thousand barrels per day	set to value of 0.0652316, or $10^3/(42 * 365)$	Million bbl yrs/ billion gal days
WPETOH	Delivered price of ethanol produced from crop *i* in Census Region *sr* in year *t* for volume step *e* for quantity of ethanol demand *WQETOH*	Mapped from *PETOH*. Read to PETTR variable in WRENEW common block	$/barrel
WQETOH	Delivered quantity of ethanol produced from crop *i* in Census Region *cr* in year *t* for volume step *e* for price of ethanol *WPETOH*	Read to QETTR variable in WRENEW common block	Million barrels/day

MODEL INPUT: *CAPCST*

DEFINITION: Capital cost for conversion technology for crop *i* in year *t*.

Given only for corn since the BSS is currently concerned only with corn as a feedstock. The current value is $1.00 per gallon on steps one, two, and three, $2.00 per gallon on step four, and $2.50 per gallon on step five of the supply curves. Costs are the same for all years. Located in the WETOHIN input data file.

SOURCE: USDA/ERS. 1988. *Ethanol: Economic and Policy Tradeoffs*. Agricultural Economic Report No. 585. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

MODEL INPUT: *COST*

DEFINITION: Outputs from the ARIMS model from cases executed at each of the price steps *p* and each of the quantity steps *e*.

Values represent the cost of producing the corn necessary to produce Q_e billion gallons of ethanol if the price were D_p in year *t*.

Values are given only for PADD 2. Quantities of ethanol produced outside of PADD 2 are currently insignificant, so all production from ethanol is shown in PADD 2. Located in the WETOHIN input data file.

SOURCE: ARIMS model outputs. David A. Trumble. 1994. *Estimation of supply Curve for Ethanol with Corn as the Feedstock.* Oak Ridge National Laboratory.

MODEL INPUT: *D*

DEFINITION: Diesel oil price steps *p*.

The diesel oil prices for which the ARIMS model was executed in each year. The BSS assumes that $COST_{p,t,e}$ was generated from a matrix of ARIMS cases for each D_p and Q_e.

SOURCE: ARIMS model inputs. David A. Trumble. 1994. *Estimation of supply Curve for Ethanol with Corn as the Feedstock.* Oak Ridge National Laboratory.

MODEL INPUT: *Q*

DEFINITION: Volume price steps *e*.

The ethanol volume steps for which the ARIMS model was executed in each year. The BSS assumes that $COST_{p,t,e}$ was generated from a matrix of ARIMS cases for each D_p and Q_e.

SOURCE: ARIMS model inputs. David A. Trumble. 1994. *Estimation of supply Curve for Ethanol with Corn as the Feedstock.* Oak Ridge National Laboratory.

MODEL INPUT: *MC_RMPUAANS*

DEFINITION: Yield on AA utility bonds for year *t*.

Located in the Macroeconomic common block, MACOUT.

SOURCE: Generated by the Macroeconomic Activity Module.

MODEL INPUT: *OPCST*

DEFINITION: Operating costs, exclusive of energy, for conversion technology of crop *i* in year *t*.

Given only for corn since the BSS is currently modeling only corn-derived ethanol. Values are: $0.30/gal. for 1990, $0.27/gal. for 2005. $0.27/gal. for 2015. Located in the WETOHIN input data file.

SOURCE: USDA/ERS. 1988. *Ethanol: Economic and Policy Tradeoffs*. Agricultural

Economic Report No. 585. Resources and Technology Division, Economic Research Service, U.S. Department of Agriculture, Washington, D.C.

MODEL INPUT: *PADD2CR*

DEFINITION: Conversion rates to convert from PADD *pr* to Census Region *sr*.

Values are given for each PADD and Census Region. Most PADD's map one-to-one to a Census Region. Only PADD 2 maps into two different Census Regions. Located in the WETOHIN input data file.

SOURCE: Generated by Dr. Anthony Turhollow, Oak Ridge National Laboratory, based on historical ethanol production from corn feedstocks.

MODEL INPUT: *PDSTR*

DEFINITION: Price of diesel for transportation in Census Region *sr* in year *t*.

Located in the NEMS Price common block (MPBLK).

SOURCE: Generated by the Petroleum Market Module.

MODEL INPUT: *PCLIN*

DEFINITION: Price of coal for industrial use in Census Region *sr* in year *t*.

Located in the Price common block, (MPBLK).

SOURCE: Generated by the Coal Market Module.

MODEL INPUT: *QEN*

DEFINITION: Quantity of energy needed to convert crop *i* to ethanol in year *t*.

Given only for corn since the BSS is currently concerned only with corn as a feedstock. Values, in million Btu per gallon, are as follows: 0.050 in 1990, 0.040 in 2005, 0.035 in 2015. This decreasing trend is based on the assumption that energy required decreases linearly over time. Located in the WETOHIN input data file.

SOURCE: Marland, G. and A.F. Turhollow. 1991. "CO_2 Emissions From the Production and Combustion of Fuel Ethanol from Corn." *Energy*, 16(11/12):1307-1316.

MODEL INPUT: *QFUEL*

DEFINITION: Quantity of fuel type *f* used in the production of crop *i* in year *t*.

Given only for corn since the BSS is currently concerned only with corn as a feedstock. Values cover seven different fuel types and 20 forecasts, and remain constant for the duration of the forecast horizon. The values for fuel type six, coal, are all zero. Fuel type seven is reserved for fuel provided for the feedstock conversion process. Located in the WETOHIN input data file.

SOURCE: Marland, G. and A.F. Turhollow. 1991. "CO_2 Emissions From the Production and Combustion of Fuel Ethanol from Corn." *Energy*, 16(11/12):1307-1316.

MODEL INPUT: *HEATCONT*

DEFINITION: Heat content of ethanol in transportation fuel, high-heating value.

SOURCE: Marland, G. and A.F. Turhollow. 1991. "CO_2 Emissions From the Production and Combustion of Fuel Ethanol from Corn." *Energy*, 16(11/12):1307-1316.

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I.9 Model Abstract

Model Name:

Biomass (Ethanol) Supply Submodule

Model Acronym:

BSS

Description:

The BSS is a supply curve model for ethanol used for transportation fuel. It utilizes an ethanol cost function, NEMS energy price data, and outputs from an exogenous agricultural resource allocation linear programming model, to produce ethanol supply curves. The ethanol cost function models the impact of corn feedstock prices and supplies, energy prices, and feedstock conversion costs on delivered ethanol prices. The BSS's primary interaction is with the NEMS Petroleum Market Module (PMM).

Purpose of the Model:

The purpose of the Biofuels (Ethanol) Supply Submodule (BSS) is to provide annual corn-derived ethanol supply-cost curves for use by the Petroleum Market Module (PMM) in projecting ethanol requirements. For each year, the BSS calculates delivered ethanol prices for different ethanol demand levels. The ethanol supply/cost projection information by Petroleum Administration for Defense District (PADD) and by Census Region. These projections are made Through the year 2015. The BSS, as a part of NEMS, help the Energy Information Administration develop forecasts published in its *Annual Energy Outlook (AEO)*.

Most Recent Model Update:

September 16, 1996

Part of Another Model?:

The Biofuels submodule is a component of the Petroleum Market Module (PMM) of the National Energy Modeling System (NEMS).

Official Model Representative:

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Documentation:

NEMS Documentation Report: *Petroleum Market Model*, 1997

Archive Media and Installation Manual(s):

Archived as part of the NEMS AEO97 production runs.

Energy System Described:

Agricultural sector—corn feedstock production net of byproducts; corn feedstock requirements for ethanol production; ethanol as a refinery input for gasoline blending.

Coverage:

- Geographic: Nine Census Regions: New England, Mid Atlantic, South Atlantic, East North Central, West North Central, East South Central, West South Central, Mountain, and Pacific. Five PADD's: Atlantic Coast, North Central, South Central, Mountain, and Pacific

- Time Unit/Frequency: Annual, 1990 through 2015

- Products: Motor Fuel/Additives

Modeling Features:

NA

Non-DOE Input Sources:

Omnibus Reconciliation Act of 1990

- $0.54 per gallon subsidy for ethanol blenders

Marland & Turhollow, 1991

- Quantity of energy needed for process conversion
- Quantity of fuel used in the production of feedstocks

United States Department of Agriculture (USDA) - Report #585

- Capitol & operating costs for conversion technologies

United States Department of Agriculture (USDA) - (ARIMS)

- Percentage of ethanol produced by PADD's
- Feedstock cost data

Anthony Turhollow, Oak Ridge National Laboratory, Oak Ridge, Tennessee

- Beta coefficients derived from an analysis of ARIMS outputs

DOE Input Sources:

- EIA coal and diesel prices

Computing Environment:

- Hardware Used: RS 6000 POWER server 590
- Operating System: AIX version 3
- Language/Software Used: AIX FORTRAN
- Memory Requirement: 26 Kb
- Storage Requirement: 14 Kb
- Estimated Run Time: 0.02 seconds
- Special Features: None.

Independent Expert Reviews Conducted:

None.

Status of Evaluation Efforts by Sponsor:

None.

I.10 Data Quality and Estimation Processes

This section provides an overview of the Agricultural Resources Interregional Modeling System (ARIMS), a main source of input data used in the BSS.

Agricultural Resources Interregional Modeling System (ARIMS)

The primary purpose of the national Agricultural Resource Interregional Modeling System (ARIMS) is as a system to analyze agricultural policies. Because resources and agricultural production practices differ by region, numerous regional attributes and responses to agricultural and resource policies can be evaluated in ARIMS. For example, policies can be evaluated that impact regional resource availability, farming techniques, resource prices, input availability, alternative levels of demand, and environmental allowances. The foremost use of the ARIMS, however, is to appraise future agricultural resource requirements.

ARIMS is a large linear programming model that includes numerous input coefficients and constraints. The inputs include projections of future resource availability, future demand levels and regional distribution of those demands, future commodity yields, and future changes in the ability of farmers to produce agricultural commodities. These projections are then used in a programming model and the composite effect of these individual impacts and the policy provisions introduced is analyzed.

The linear programming model of the agricultural sector is a set of mathematical relationships incorporating characteristics most relevant to agricultural production. The model minimizes the cost of producing and transporting agricultural commodities as required to meet pre-specified demands.

ARIMS divides the Nation into eight economic sectors. These eight sectors, integrated by a linear programming framework, are designed to represent the production processes and driving forces of U.S. agriculture.

The modeling system incorporates three different regional definitions. Production of agricultural commodities includes 105 Crop Producing Areas and 31 Livestock Producing Areas. The grazing

production sector is specified for a third set of regions—34 ecosystems. The 31 Livestock Producing Areas also serve as the regional structure for non-water input purchases. In addition to the regions explicitly contained in the model structure, coefficients are developed by county, State, USDA farm production region and Major Land Resource Area.

Livestock markets (cattle, hogs, poultry) have an important role in determining the supply price of ethanol. The vast bulk of grain produced in the United States is fed to livestock, and the by-products of producing ethanol from corn (gluten meal, gluten feed, and distillers dried grains) are either fed to domestic livestock or exported. The by-products, including corn oil, from converting corn into ethanol are typically valued at about 50 percent of the raw corn cost.

The value of the by-products is directly proportional to the caloric and protein values of the feed by-products. Gluten meal (60 percent protein) and gluten feed (20 percent or more protein) are high in protein relative to corn (9 percent protein) and thus have a strong impact on soybean meal prices and vice versa. Soybean meal is 44 percent or more protein and is the main protein supplement for livestock. This competitive interaction is captured in the ARIMS model. As ethanol production from corn increases, the unit value of the feed by-products tends to decrease.

As an example, with corn at $2.50 per bushel the by-products are worth $1.25 per bushel, so the net feedstock cost is only $1.25 per bushel. At a conversion rate of 2.5 gallons of ethanol per bushel of corn, the net feedstock cost is only $0.50 per gallon instead of $1.00 per gallon.

The only use of ARIMS in this submodule is as a source of feedstock cost data. Regression equations relating the cost of corn to energy input prices were estimated from successive runs of the model. However, the summary statistics of those regressions are not currently available as they were conducted off-site and were not included in subsequent reports.