EIA Model Documentation

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**PETROLEUM MARKET MODEL
OF THE
NATIONAL ENERGY MODELING SYSTEM**

Part 2

December 18, 1997

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

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APPENDIX C Bibliography

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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, 3 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 1997

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 1997. (DOE/EIA-M059).

D.10 Archive Media and Installation Manual

Archived as part of the NEMS AEO98 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); three refining regions (PAD District I, an aggregate of PAD Districts II-IV, and PAD District 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 2020

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 4.2
Software:	AIX FORTRAN, OML
Memory Requirement:	8,500K
Storage Requirement:	55 MB
Estimated Run Time:	619 seconds in a full NEMS run (31 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
N. Yamaguchi, Trans-Energy Research Associates, Inc., November 1997.

D.18 Status of Evaluation Efforts by Sponsor:

None.

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 1996¹. 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 1996*, (http://www.eia.doe.gov/oil_gas/pma96/pma96frame.html, November 1997). 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 1994 (SEPER). The methodology behind these state-level sectoral prices are discussed in the *State Energy Price and Expenditures Report 1994* (DOE/EIA-0376(94)). 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(94) (SEDS)).

Due to a two-year lag in the publication of the SEPER data, end-use price estimates for 1995 and 1996 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 1996 (DOE/EIA-0348(96)) for a discussion of 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
Liquefied 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, February 1997, 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.

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

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 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

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

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

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

²Bonner & 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).

³Ensys 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).

$$PVNTPE_i = \frac{NTPE_i}{3} \sum_{j=1}^3 (1+DEF)^j \quad (2)$$

where DEF = inflation rate during construction

The final land, plant, and equipment cost is

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

where S = Special costs multiplier (includes land)

C = Contingency cost multiplier

The total investment is

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

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:

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

where,

CRT_{ij} = 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

<u>PAD District</u>	<u>Location Factor</u>
I	1.2
II - IV	1.07
V	1.4

when $R > 0$, then

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

otherwise,

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

Also,

$$TR_j = TRF + TRS_j - TRF \times TRS_j$$

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,

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

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:

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

where

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

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

Table F3. Fixed Cost Multiplier Values

<u>Multiplier</u>	<u>Value</u>
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 data⁴ so that data variability is unknown. The five multipliers are shown in Table F5.

Table F5. Total Dry Gas Multiplier

<u>PAD District</u>	<u>Multiplier</u>
I	0.4536
II	0.7659
III	0.7572
IV	1.0136
CA	0.7745

⁴Energy 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 report⁵. The liquids extraction data have been calculated by averaging actual liquid extraction volumes from the 4-year period 1990 - 1993⁶ 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 economics, 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	R HS
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 (MMcf)	-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	≤	+

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

⁶Energy 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 demand⁷. Their forecast is:

Table F7. Chemical Industry Demand for Methanol

<u>Year</u>	<u>Demand (Mbb/d)</u>	<u>Year</u>	<u>Demand (Mbb/d)</u>
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.

⁷Pace 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 maintenance expenses over three time periods: 1991-1995, 1996-2000, and 2000-2010. Operation and maintenance 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 same fixed costs are assumed for forecast years 2011 through 2020.

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 assumed¹⁰.

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 age¹¹.

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 estimates¹².

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

⁹Ibid, Section V-9-12.

¹⁰Ibid, Section V-13.

¹¹Ibid, Section V-16.

¹²Ibid, 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 API¹³, 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 Environmental 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, kerosene, 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 PAD District costs were allocated to their perspective PMM regions.

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 unnecessary 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).

¹³The 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.

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

- (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.

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

$$\begin{aligned}\text{REVL}P(LP)_R &= \text{VALUE}(LP)_R * \text{VOLUME}(LP)_R \\ \text{REVHP}(HP)_R &= \text{VALUE}(HP)_R * \text{VOLUME}(HP)_R\end{aligned}$$

where:

$\text{VALUE}(LP)$ is the marginal price for each light product (LP) that will bear the fixed cost
 $\text{VALUE}(HP)$ is the marginal price for each heavy product (HP) that will not bear the fixed cost
 $\text{VOLUME}(LP)$ is the production volume for each light product
 $\text{VOLUME}(HP)$ is the production volume for each heavy product
 $\text{TOTREV}_R = \text{REVL}P(LP)_R + \text{REVHP}(HP)_R$

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

$$\begin{aligned}\text{NTOTREV}_R &= \text{REVL}P(LP)_R + \text{REVHP}(HP)_R + (\text{FIXCOST}_R * \text{VOLUME}) \\ \text{NLTREV}_R &= \text{NTOTREV}_R - \text{REVHP}(HP)_R\end{aligned}$$

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

$$\text{GATEPR}(LP)_R = (\text{NLTREV}_R / \text{REVL}P(LP)_R) * \text{VALUE}(LP)_R$$

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 1996. 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) 1994. End-use prices after 1994 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)
BBM6007.A.SASDB.STATE.AB9697
(IMP96A)
PRJ6007.NEMS.MARKUP.SASDB
(REGIONS)
(WHOLSALE)

This program reads 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. Due to the number of data, prices for 1994 and 1995 are kept in a separate file than 1996 data. 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)
BBM6007.A.SASDB.STATE.AB9697
(IMP96B)
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, IMP95B, and IMP96. 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, 1995 and 1996, 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 chain weighted GDP deflators (1987 base) 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 CONVER96)

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.PUBLIC94.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 E759Y96)
PRJ6944.F759.MASTER96

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. Contact Melvin Johnson (202)426-1176.

Program: PRJ6007.NEMS.MARKUP.F423.READ

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
PRJ6501.F423.EXTR1996.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. Contact Ken McKleevey (202)426-1144.

Program: PRJ6007.NEMS.MARKUP.ARVOL

Files Read: PRJ6356.SEDS.PUBLIC94.DATA
PRJ6007.NEMS.MARKUP.SASDB
(ARVOL84 through ARVOL94)

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 ARVOL94. 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.PUBLIC94.DATA
PRJ6007.NEMS.MARKUP.SASDB
(KERVOL84 through KERVOL94)

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 KERVOL94. The location of the volume should be incremented by 14 (@329+14).

Program: PRJ6007.NEMS.MARKUP.GASVOL

Files Read: PRJ6356.SEDS.PUBLIC94.DATA
PRJ6007.NEMS.MARKUP.SASDB
(GASVOL84 through GASVOL94)

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 GASVOL94. The location of the volume should be incremented by 14 (@329+14).

Program: PRJ6007.NEMS.MARKUP.LPGVOL

Files Read: PRJ6356.SEDS.PUBLIC94.DATA

PRJ6007.NEMS.MARKUP.SASDB
(LPGVOL84 through LPGVOL94)

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 LPGVOL94. The location of the volume should be incremented by 14 (@329+14).

Program: PRJ6007.NEMS.MARKUP.RSVOL

Files Read: PRJ6356.SEDS.PUBLIC94.DATA
PRJ6007.NEMS.MARKUP.SASDB
(RSVOL84 through RSVOL94)

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 RSVOL94. 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 GASVOL94)
(CONVER84 through CONVER96)
(RGAL87)
(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 1994 are used to represent 1995 and 1996, since SEDS stops with 1994 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 STATE94)
(PRODE)
(ARVOL94)
(GDP87CH)
(CONVER84 through CONVER96)
(RGAL82)
(ARBTU)
(MARKAR)

This program uses State-level asphalt and road oil prices to the industrial sector from SEPER's through 1994. End-use prices for 1995 and 1996 are estimated using the 1995 and 1996 changes in the EIA-782 high sulfur residual fuel prices. Prices for each Census division are calculated using 1994 volumes from the SEDS. Estimates for 1995 and 1996 are weighted using 1994 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 STATE95, use ARVOL95 and CONVER97, 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 STATE94)
(PRODE)
(KEROVOL94)
(GDP87CH)

(CONVER96)
(KEROGAL)
(KEROBTU)
(MARKOTH1)

This program uses State-level kerosene prices to the residential, commercial, and industrial sectors from SEPER's through 1994. End-use prices for 1995 and 1996 are estimated using the 1995 and 1996 changes in the EIA-782 distillate prices. Prices for each Census division are calculated using 1994 volumes from the SEDS. End-use price estimates for 1995 and 1996 are weighted using 1994 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 STATE95, use KERVOL95 and CONVER97, and increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.RESID.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(PRODE)
(WHOLSALE)
(STATE84 through STATE94)
(RSVOL94)
(GDP87CH)
(CONVER84 through CONVER96)
(RSGAL)
(RSBTU)
(MARKRL)

This program uses State-level residual fuel prices to the commercial, and industrial sectors from SEPERs through 1994. End-use prices for 1995 and 1996 are estimated using the 1995 and 1996 changes in the EIA-782 low sulfur residual fuel prices. Commercial and industrial prices for each Census division are calculated using 1994 volumes from SEDS. Price estimates for 1995 and 1996 are weighted using 1994 volumes. Residential prices are estimated using 1995 and 1996 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 STATE95, use RSVOL95 and CONVER97, and increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.RHTR.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB

(PRODE)
(WHOLSALE)
(STATE84 through STATE94)
(PRODE)
(REGIONS)
(EUSTATE)
(RSVOL94)
(GDP87CH)
(CONVER96)
(RSTRGAL)
(RSTRBTU)
(MARKRHTR)

This program uses State-level residual fuel prices to the transportation sector from SEPERS through 1994. End-use prices for 1995 and 1996 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 1994 volumes from SEDS. End-use price estimates for 1995 and 1996 are weighted using 1994 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 STATE95, use RSVOL95 and CONVER97, and increment all year dependent formulas.

Program: PRJ6007.NEMS.MARKUP.LPG.CALC

Files Read: PRJ6007.NEMS.MARKUP.SASDB

(PRODE)
(WHOLSALE)
(STATE84 through STATE94)
(PRODE)
(REGIONS)
(LPGVOL94)
(GDP87CH)
(CONVER96)

(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. Post-1993 prices for all sectors 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 STATE95 use LPGVOL95 and CONVER97. 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 STATE94)
(PRODE)
(REGIONS)
(UTDIV)
(E759Y84 through E759Y96)
(GDP87CH)
(CONVER84 through CONVER96)
(EURFRGAL)
(EURFBTU)
(MARKELEC)

This program uses State-level SEPER's prices for distillate, high sulfur, and low sulfur residual fuel to electric utilities through 1994. End-use prices for 1995 and 1996 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 CONVER97, and E759Y97.

Program: PRJ6007.NEMS.MARKUP.CREATE.FLATFILE

Files Read: PRJ6007.NEMS.MARKUP.SASDB
(MARKPMM)
(MARKLPG)
(MARKRL)
(MARKRHTR)
(MARKOTH1)
(MARKAR)
(MARKELEC)
PRJ6007.MARKUP.NEMS.MU1PRDS.D061997a
PRJ6007.NEMS.MARKUP.DOL96.D061997a

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 1996 dollars and outputs to a file.

To update: Update the GDPCH87 deflator, GDPDEF96.

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 97, and months 01 and 07 (except for 1990 when the months are 01 and 08)

Sources:	gasoline	Federal Highway Administration
	diesel	Federal Highway Administration
	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.DLPJTyy

Inputs: annual tax information back to 1995. The state level lpg taxes are from Federal Highway while the jet fuel taxes are EIA's Petroleum Marketing Division

Outputs: STLPJTyy

Sources: LPG Federal Highway Administration
jet fuel EIA, Petroleum Marketing Division

This series of programs (LPJT95 through LPJT97) was created in 1997 to incorporate state level lpg and jet taxes which had not previously been collected. A snapshot of annual taxes is reproduced for each month to create files with the same data for each month.

Program: PRJ6007.NEMS.TAX.CALC95b

(Old Version): PRJ6007.NEMS.TAX.CALC94

Inputs: STYMMMM 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
STLPG_MO
STJET_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. The program was revised in 1997 to incorporate state taxes for LPG and jet fuel back to 1995. Sales volumes and regional designations are added to facilitate volume weighting across time and regions as required. Refiner and marketer volumes are used to weight LPG taxes as Census division 1 and 2 data were missing in the A data. Product 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
STLPG_MO
STJET_MO

Outputs: STGAS_YR
STDES_YR
CDGAS_YR
CDDES_YR
STLPG_YR
STJET_YR
CDLPG_YR
CDJET_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.

Program: 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:

Inputs: PRJ6007.NEMS.TAX.SASDB:STLPGJT97
PRJ6007.NEMS.TAX.SASDB:STM85E85
PRJ6007.NEMS.MARKUP.SASDB:REGIONS
PRJ6007.NEMS.A.SASDB.STATE.AB9697:IMP96A
PRJ6007.NEMS.A.SASDB.STATE.AB9697:IMP96B (use for LPG
because CD's 1 AND 2 EI-782A data are missing)
(Old versions): PRJ6007.NEMS.TAX.DLPGJET.Y94
PRJ6007.NEMS.TAX.DM85E85.Y94

Outputs: PRJ6007.NEMS.TAX.SASDB:LPGCAST
PRJ6007.NEMS.TAX.SASDB:JETCAST
PRJ6007.NEMS.TAX.SASDB:E85CAST
PRJ6007.NEMS.TAX.SASDB:M85CAST

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

Inputs: GASCAT
DIESCAT
LPGCAST
JETCAST
E85CAST
M85CAST

Outputs: PRJ6007.NEMS.TAX.TAXFILE

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 three 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.

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	9.5/11.0	8.7/NA	8.7/11.0	8.2/NA
1998-1999	9.1/11.0	8.7/NA	8.5/11.0	7.9/NA
2000-Forward				

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

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

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 1990¹⁶. 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 severe ozone problems as well as in areas with less severe ozone problems 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 north¹⁷ 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.

¹⁶Federal 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)

¹⁷For 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 presentation¹⁸ 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 EPA¹⁹, 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.

¹⁸C.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.

¹⁹Ibid.

**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

Within the PMM, total gasoline demand is disaggregated into demand for traditional (TRG), oxygenated (TRH), and reformulated (RFG) gasolines by applying assumptions about the annual market shares for each type. Annual assumptions for each region account for the seasonal and city-by-city nature of the regulations. The market shares are assumed to remain constant at the 1996 level, with minor adjustments reflecting known changes in oxygenated or reformulated gasoline programs. The 1996 market shares are based on 1996 sales volume data from EI-782C, "Monthly Report of Prime Supplier Sales of Petroleum Products Sold for Local Consumption." The Census Division 4 market shares are adjusted to reflect the statewide and year-round requirement for oxygenated gasoline in Minnesota beginning in 1997. The Census Division 8 market shares reflect the 1997 opt-in of Phoenix, Arizona to the Federal reformulated gasoline program. Although several areas are considering a reformulated gasoline requirement, they have yet to submit formal opt-in proposals to the EPA.

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

F.9 Estimation of Low-Sulfur Diesel Market Shares

The CAAA90 mandates the use of low sulfur diesel for on-highway use.. 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 1996* (online: http://www.eia.doe.gov/oil_gas/fok/1996/fokframe96.html, November 3, 1997). 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.

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									SUM
	1	2	3	4	5	6	7	8	9	
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 1999²⁰. 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

²⁰Proposed Rules, Federal Register, Vol. 57, No. 130, July 7, 1992, pp. 29960-29961.

million 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-810²¹.

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.

The PMM 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:

$$\text{Possible Allowance Volume (PAV)} = \text{total distillate} * .128 * .59$$

(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 weight²². 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:

$$\text{Possible Allowance Weight (PAW)} = \text{PAV} * (302/2000 \text{ tons/bbl})$$

(MMtons)

and

$$\text{Requested Allowances} = \text{PAW} * (0.00224 \% \text{ wt}) * 2$$

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

²¹Ibid.

²²The 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:

The EIA-810 started to differentiate between low sulfur diesel and other distillate in 1993. Annual data can be used to calculate the percent of low sulfur diesel produced at small refineries. The PMM methodology should be updated to replace the 59-percent assumption with a historical percentage..

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.

$$\begin{aligned}\text{U.S. Unfinished Oil Imports} &= -2856.7 + (0.2447 * \text{Crude Inputs}) \\ \text{t-stats: } &(-157.5) \quad (8.97) \\ \text{R-squared: } &.95\end{aligned}$$

$$\begin{aligned}\text{PAD District III Unfinished Oil Imports} &= \text{U.S. Unfinished Oil Imports} * 0.65 \\ \text{PAD District III Naphthas} &= \text{PAD District III Total} * 0.24 \\ \text{PAD District III Heavy Gas Oils} &= \text{PAD District III Total} * 0.27 \\ \text{PAD District III Residuuum} &= \text{PAD District III Total} * 0.49\end{aligned}$$

$$\begin{aligned}\text{PAD District I Unfinished Oil Imports} &= \text{U.S. Unfinished Oil Imports} * 0.35 \\ \text{PAD District I Naphthas} &= \text{PAD District I Total} * 0.09 \\ \text{PAD District I Heavy Gas Oils} &= \text{PAD District I Total} * 0.73 \\ \text{PAD District I Residuuum} &= \text{PAD District I Total} * 0.18\end{aligned}$$

F.14 Product Pipeline Capacities and Tariffs

Two sources were used to obtain the product pipeline data; (1) The NPC study²³ 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.

²³National 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 Tariffs²⁴

Census region			
From	To	Capacity (Mbbbl/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

²⁴Capacities and tariffs from NACOD model.

The LPG/NGL pipelines are shown in Table F19.

Table F19. LPG/NGL Pipelines Capacities and Tariffs²⁵

Census Region			
From	To	Capacity (Mbbbl/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".

²⁵Capacities 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:

<u>REGION</u>	<u>PERCENT SOLD TO GRID</u>
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.JDLCOGEN.HISTORY94.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.JDLCOGEN.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,²⁶ the target prices declined across the three vectors.

²⁶ 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

G.1 Introduction

The purpose of this appendix is to describe the program which runs the Multi-Refining Model (MRM) (3-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 3-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 3-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 3-region MRM models the 5 U.S. PADDs, aggregated into 3 regions and labeled as follows: E = PADD I; B = PADDs II, III, IV; W = PADD V.

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, gives a brief description of the set, and provides 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 W: crude pipeline from supply reg 3 to PADD III B: Barge residual oil I: West Texas to PADD II J: U.S. flag light products O: U.S. flag LPG R: PADD III loop to PADD II S: PADD III capeline to PADD II T: Light product pipeline U: LPG, C4, CC5 pipeline V: Barge residual oil X: Local transportation Y: Pipeline PADD II to demand 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	3	Refining regions	E: PADD I B: PADD II, PADD III, PADD IV W: PADD V
t	2	Type of transportation	V: Vessel P: Pipeline
x	5	Exporting regions	2: Export cd for PADD I (region E) 3: Export cd for PADD II (region B) 7: Export cd for PADD III (region B) 8: Export cd for PADD IV (region B) 9: Export cd for PADD V (region W)
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
Qs	3	Step label for crude oil imports	Q1, Q2, Q3
Rs	9	Step label for product imports	R1, ..., R9,

Index	No. of Values	Description	Members
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
x		A@METDEM	Methanol demand accounting row in US

MRM	ERM	Name	Constraint Represented
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 imports 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 plant 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)
x		O(o)(crt)	Domestic crude oil (crt) accounting in (o)

MRM	ERM	Name	Constraint Represented
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 (3 regions)	8303	335	3373	2541
ERM (single region)	2274	38	914	709

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.

Source Code	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 (not used)
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 (5-reg only)
mrm.f	mrmparam, mrmpath main.dat ermparam paihe maine.dat	Program MPS2ANAL: 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

Source Code	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 (5-reg only)
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
transit3.f	transit.dat	Simulates the product and crude oil transportation for the 3-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. The following gives 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 coefficients.

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

distblend.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	

	I(d)(pi9)Z9	D(d)(px9)Z9
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) = region G only (i.e., single region)

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) = region G only (i.e., single region)

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) = region G only (i.e., single region)

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		

	C(d)ETHR(i)	Z(d)ETHTAX	X(d)ETHE85
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	-x	
S(r)RFGOXY			-x
U(r)KWH		-x	
A(r)(xxx)(mgb)	x		

	B(r)(mgb)(ist)	Q(r)(mgb)	Z(r)RFGOXY
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

	E(r)MOHINV	L(r)MOHBLD	K(r)MOHCAP	G(r)MOH01
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

	I(r)(pri)*R(s)	I(r)(pri)**R(s)
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
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

	E(r)(uns)INV	K(r)(uns)CAP	L(r)(uns)BLD	T(r)OVCOBJ	R(r)(uns)(mod)
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(trr)
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		

	X(d)ETH(xxx)	X(d)METM85	X(d)(www)SPG	B(r)RFG(sss)	B(r)RFG(rrr)
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
A@PRDRFN		x

tabread.f: This subroutine prints the data file names, the number of tables and lists the tables names that are read.

transit3.f: This subroutine simulates the transportation network for MRM 3-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		

	Y(o)*(crt)(m)(r)	W(d)ETH(r)	W(r)MET(d)	W(s)(prd)(d)	V(xxxxxx)
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 refinery (r) regions; ** for (r)=Census Division
 *** for (prd) different than MET, ETH; **** for (prd) = LPG and PCF;
 (s) : refinery (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)KWGPGRN	T(r)NGFNRS
U(r)(uuu)	x	x**	-x***
OBJ	-x		
A@KWHRFN	x*	x	
B(r)NGS			x
A(r)NGSRFN			x

	U(r)(uuu)	R(r)KWGPNG	T(r)NGFNGS
A@NGFTOT	x***		
A(r)NGFTOT	x***		
Z(r)NGFSUM	-x***		

*: for (uuu) = KWH ; **: for (uuu) = KWH and STM; ***: for (uuu) = NGF

utility.f: This subroutine is the same as utility.f, except that it is for ERM, and (r)=refinery region G only (i.e., single region).

All the Fortran files are located on the EIA RS-6000 in the directory /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 consist 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	/default/includes/ipmmtest
IPMMINT	Common for integer variables shared by subroutines that generate submatrices	/default/includes/ipmmtest
IPMMCHAR	Common for character variables shared by subroutines that generate submatrices	/default/includes/ipmmtest
LPTAB	Common used for solution retrieval and report writing	/refine/pmm_lp_gen/includes/lpout
OMLREAL	Common for real variables used to set LP memory size	/default/includes/omlspace
OMLINT	Common for integer variables used to set LP memory size	/default/includes/omlspace
DFINC2	Common for OML database functions	/default/includes/dfinc2
WCR	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
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
VEPLAS	(r)	(year)	Electric utility prices (\$/kwh)

* except NGF

cogener.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.

distblend.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)	Y96	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, C4, R4	(year)	Ethanol supply curves
ETHTAX	TAXETH, TAXE85	(year)	Ethanol taxes; tax subsidy

fixcols.dat (no longer used)

Table	Columns	Rows	Description
FIXCOL	R	Dummy	First letter of column to fix
(f)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	Y1, Y2, Y3, Y4, Y5	RFG(spec); YEAR	Gasoline specs for subspec SSR ; year of data
(r)SST	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline specs for subspec SST; year of data
(r)SSE	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline specs for subspec SSE; year of data
(r)RFH	Y1, Y2, Y3, Y4, Y5	RFG(spec); YEAR	Gasoline spec for RFH; year of data
(r)TRH	Y1, Y2, Y3, Y4, Y5	TRG(spec); YEAR	Gasoline spec for TRH; year of data
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
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	Linked list of refinery and demand regions	List of demand region
USERYEAR	YEAR	YR96	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
(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	FAC, CAP, LIM, PCU	Gas plant capacity limits
CC1CAP	(r)01	(year)	Dry gas production capacity

prdex.p.dat

Table	Columns	Rows	Description
(x)PRDEXP	MINY1, MAXY1, MINY2, MAXY2, ... MINY5, MAXY5	(prx), YEAR	Limit on volume to export; year of data
EXPLIM	YRPC, FIX	1995	Limit on volume and yearly increase
MULTEXPR	MULT	PRICE	Price for exports as function of imports

(x) = export regions (CDs 2,3,7,8,9).

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)	(m)(r)	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

Table	Columns	Rows	Description
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
PLLBR(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

** refinery (r) and demand (d) regions

unfinish.dat

Table	Columns	Rows	Description
UNFOIL	E, B, 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	NGFNCS	BFOE natural gas.
(r)UAP	CST	(uuu)	Utility costs.
VALPNG	(r)	(year)	Industrial price of natural gas.
VPELIN	(r)	(year)	Industrial elec utility prices (\$7\$/kwh)

utilitye.dat

Table	Columns	Rows	Description
UTITRS	COEF	NGFNCS	BFOE natural gas.
GUAP	CST	(uuu)	Utility costs.

G.3.b Other input files

1. mrrmparam file

The mrrmparam file¹ is a control file read by main.f to map input and output file names and instructions. In the mrrmparam, 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 mrrmparam file.

Variable name	Variable length	Variable purpose	Restrictions
MODELN	8	Model to be run	MRM3, 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. Appendix G-A provides an example of an mrrmparam file. The mrrmparam 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.

¹Note that the default file used for the MRM is named "mrrmparam," while that used for the ERM is named "ermparam." Before an ERM execution can be run, the ermparam name must be renamed to mrrmparam.

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	'MRM3	!	8
ACTPROB	'OMLMRM3	!	8
SOLNAM	'MRM3SOL	!	8
PATHNF	'mrmpath'	!	7
TITLE	'MRM3 MULTI REGION REFINERY	!	48
INBASISN	'inbasis3	!	48
OUTBASISN	'outbasis3'	!	9
BASISN	'MRM3	!	9
MPSOUTN	'mrm3mps	!	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 3-region MRM model and the ermparam file will run the single region ERM model; the act problem will be "OMLMRM3" for the MRM model and "OMLERM" for the ERM model; the solution name will be "MRM3SOL" 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 "MRM3, MULTIPLE REGIONS REFINERY" and the ERM model will be "ERM, SINGLE REGION REFINERY;" the advanced basis will be read from "inbasis3" for the MRM model and "inbasise" for the ERM model along the path defined; the optimal basis will be stored in the file "outbasis3" for the MRM model and "outbasise" for the ERM model; both the advanced and optimal basis will be named "MRM3" for the MRM model and "ERM" for the ERM model; the mps file will be stored in "mrm3mps" 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

mrmrpath:

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/cogener.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/main.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/utility.dat.v1.1
mchproc	
limpol	/default/input/limpol.dat.v1.2
unfinished	
prdex	
akaexp	
foreign1	
foreign2	
fsu	
intsetup	
epsetup	
bldhead	
bldstub	
ENDATA	

Appendix G-C:Makefile

```
FLAGS=-c -g -C -qcharlen=16384 -qmaxmem=-1 -qnoprint \
-qfltrap=zerodivide -qsave
INC=-I/refine/pmm_lp_gen/includes/ -I/default/includes
LIBS=-lwhiz -ldb -lutil -L/usr/lpp/MPS/om/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)llookup.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)distbld.v1.2.o \
$(LIR)gasobld.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: $(OBS)
xlf -o mrm -g -C $(OBS) $(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)utility.v1.2.o: $(SIR)utility.f
    xlf $(FLAGS) -o $(LIR)utility.v1.2.o $(INC) $(SIR)utility.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    RFCRDL48(6)
REAL    RFQICRD(6)
REAL    RFIMCR(6)
REAL    RFQISPR(6)
REAL    RFIMTP(6)
REAL    RFQEXCRD(6)
REAL    RFPQNG(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    RFCRDOH(6)
REAL    OTHOXY(6)
REAL    QPRDIMD(11,23)
REAL    QPRDEXD(6,23)
COMMON/LPTAB/PRDPRC,BASECAP,BASEUTL,INVCAP,INVUTL,TOTCAP,
+TOTUTL,PUTL,RFCRDCR,RFCrAKA,RFCrL48,RFQICRD,RFIMCR,
+RFQEXCRD,RFPQNG,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,
+RFCRDOH
  
```

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 DFPMDL
INTEGER DFP MCPY
INTEGER DFPSDEL
INTEGER DFP SCPY
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 DFMCVL
INTEGER DFMMVAL
INTEGER DFMCRHS
INTEGER DFMCRNG
INTEGER DFMCBND
INTEGER DFMRRTY
INTEGER DFMRRSC

```

INTEGER DFMRCSC
INTEGER DFMRVAL
INTEGER DFMRRHS
INTEGER DFMRRNG
INTEGER DFMRBND
INTEGER DFMROW
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 DFSINT
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, XCHRS, 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, XCOMPSPW, XCRASHSW,
* XCYCLESW, XDEGEND, XDEGMAX, XDEMAND, XDETAIL,
* XDOATTN, XDDELTM, 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 XCOMPSTW
 INTEGER XCRASHSW
 INTEGER XCYCLESW
 INTEGER XDEGEN
 INTEGER XDEGMAT
 INTEGER XDEMAND
 INTEGER XDETAIL
 INTEGER XDOATTN
 INTEGER XDODELTM
 INTEGER XDOWEAS
 INTEGER XDOWFREQ1
 INTEGER XDOWNFS
 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 XSPLNZ
 INTEGER XTIMESAV
 INTEGER XTRACE
 INTEGER XTRAN
 INTEGER XUNBDNDX
 INTEGER XUSEFREE

C

INTEGER WFINIT
 INTEGER WFDEF
 INTEGER WFSET
 INTEGER WFMPSTN
 INTEGER WFMPSTOU
 INTEGER WFLOWD
 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	WFCOL
C		
	INTEGER	WFRIVAL
	INTEGER	WFRLIST
	INTEGER	WFCLIST
	INTEGER	WFSPT
	INTEGER	WFSFILE
	INTEGER	WFCORD
	INTEGER	WFRPT
	INTEGER	WFRFILE
C		
	INTEGER	WFSVEB
	INTEGER	WFLOADB
	INTEGER	WFPUNCH
	INTEGER	WFINSRT
C		
	INTEGER	WFMGDMF
	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 conversion 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 -.04 for (respectively) for modes: A70,A85,B70,B85,C70,C85,D70,D85,E70,E85,F70,F85,G70,G85,H71,H85,I70,I85,J70,J85,K70,K85,70A,85A,70B,85B,70C,85C,70D,85D,70E,85E,70F,85F,80G,85G,71H,85H,70L,85L,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
recipes.dat:	DATA	T:GCC
	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**
Alkylation 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 hydrocracker	HCR
Residum hydrocracker	HCV
Naphta hydrocracker	HCN
High density jet fuel hydrotreating	HDN

Refinery Process	Abbreviation
Hydrogen/fuel gas reformer hydrogen	HLO**
H2-stream reformer	H2P
H2-partial oxidizer	H2X
Hydrogeneration normal pentenes/hexenes	H56*
High density jet fuel prefractionation	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

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:PBTU9096.
- 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(MSPRICE) using estimates from PFPRICES.WK4.
- 5) PRJ6007.ELCG.FLATFILE.DATA:MBL,CRDWHPR,CRPRODAY (bbl/day) updated by Ted.
- 6) PRJ6007.COGEN.F867.SASDB:ddmmdyy1 updated by cogen program. Updated cogen data was not updated with this program in AEO98.

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.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

- 3) 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

- 4) 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

- 5) 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:PBTU9096
PRJ6007.ELCG.FLATFILE.DATA(MSPRICE)

Output file: PRJ6007.PRICES.HIST.SASDB:PRDPRIC

- 6) PRJ6007.PMM.PROCESS.DEMAND - reads sectoral demand from SEDS, estimates most recent 2 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

- 7) 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:

8) 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\logirs

In Access:

Open database c:\logirs\getpsa.mdb

click on macro

run delete_and_append_records2

This will recreate tables:text_to_value1 and text_to_value2 (by deleting values 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 estimate 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.STIFSIL.monny.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.

¹The 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.IMP96.ADF	reads monthly data for 1996
PRJ6007.A.IMP96ANN.ADF	reads annual data for 1996

New files should be created each year with the year indicated in the file name.

Input files:	PRJ6015.E782P.R.DATA.ADF.D1996mm.RLSE3 (for final annual update of the monthly data, where mm represent months)
	PRJ6015.E782P.R.DATA.ADF.D1996mm.RLSE2 (for monthly data where mm represents months)

Output files:	IMP96A	contains refiner data only
	IMP96B	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. The end-use transportation prices include State and Federal taxes but for jet fuel and LPGs the State taxes are not included prior to 1995.

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.IMPpyANN.ADF for the EIA-782 annual data). Run EIA856.READ95.PORT as needed for analytical purposes.

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 throughout the NEMS forecast period. 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.

¹All 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.

²The 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.

³Energy 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 are currently set at zero. 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 thru 31. (The AEO98 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.

1.5 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.

⁴Lee, 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 4 years, corresponding to years 1, 16, 26, and 31. 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.

⁵All ethanol produced is assumed to be delivered to refineries.

Table 3. Corn Production Cost Skeleton Matrix (\$/gal)

Year	Diesel Price (\$/MMBtu)	Production Quantity Points (Billion gallons)					
		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
2015	12	0.333	0.360	0.382	0.400	0.443	0.551
2015	14	0.350	0.383	0.403	0.423	0.461	0.598
2020	6	0.237	0.266	0.295	0.323	0.352	0.468
2020	8	0.265	0.294	0.323	0.352	0.381	0.496
2020	10	0.294	0.322	0.351	0.380	0.409	0.524
2020	12	0.322	0.351	0.379	0.408	0.437	0.552
2020	14	0.350	0.379	0.408	0.437	0.465	0.581

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:

$$FC_{pr,t,e} = COST_{p-1,t,e} + \frac{PDIESEL_{pr,t} - D_{p-1}}{D_p - D_{p-1}} (COST_{p,t,e} - COST_{p-1,t,e}) \quad (I-1)$$

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, $1990 \leq t \leq 2020$

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:

$$PETOH_{i,pr,t,e} = FC_{pr,t,e} + CAPCST_{i,t} * CCF + OPCST_{i,t} + QEN_{i,t} * PEN_{pr,t} - SUB \quad (I-2)$$

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 $(10^{-9} \$ \text{ year/gal}^2)$ 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:

$$CCF = MC_RMPUAANS_t * (1 + MC_RMPUAANS_t)^8 / ((1 + MC_RMPUAANS_t)^8 - 1) \quad (I-3)$$

where:

$MC_RMPUAANS_t$ = 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:

$$WQETOH_{(cr=3,4),t,e} = Q_e \cdot PADD2CR_{2,3} \cdot QSRFACT \quad (I-4)$$

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:

$$WPETOH_{(cr=3,4),t,e} = PETOH_{1,pr,t,e} \cdot PADD2CR_{2,3} \cdot PETOHSRFACT \quad (I-5)$$

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
<i>CAPCST</i>	Capital cost for conversion technology for crop <i>i</i> in year <i>t</i>	USDA/ERS. 1988. Report #585	\$/gallon
<i>COST</i>	Cost of producing corn in PADD 2 at diesel price step <i>P</i> in year <i>t</i> at volume step <i>e</i>	ARIMS Output Trumble. 1994	\$/gallon
<i>D</i>	Values of diesel price steps <i>p</i>	Trumble. 1994	\$/MMBtu
<i>Q</i>	Quantity at each volume step <i>e</i>	Trumble. 1994	billion gallons
<i>MC_RMPUAANS</i>	Yield on AA utility bonds for year <i>t</i>	Macroeconomic Market Module	Dimensionless
<i>OPCST</i>	Operating costs, exclusive of energy, for conversion technology of crop <i>i</i> in year <i>t</i>	USDA/ERS. 1988. Report 585	\$/gallon
<i>PADD2CR</i>	Conversion rates to convert from PADD <i>pr</i> to Census Region <i>sr</i>	A. Turhollow	Dimensionless
<i>PDSTR</i>	Price of diesel for transportation in Census Region <i>sr</i> in year <i>t</i>	Petroleum Market Module	\$/gallon
<i>PCLIN</i>	Price of coal for industrial use in Census Region <i>sr</i> in year <i>t</i>	Coal Market Module	\$/MMBtu
<i>QEN</i>	Quantity of energy needed to convert crop <i>i</i> to ethanol in year <i>t</i>	Marland & Turhollow. 1991	MMBtu/gallon
<i>QFUEL</i>	Quantity of fuel type <i>f</i> used in the production of crop <i>i</i> in year <i>t</i>	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
<i>CCF</i>	Capital cost factor	Accounting Parameter	Dimensionless
<i>HEATCONT</i>	Heat content of ethanol	Value set to 3,5448	MMBtu/Bbl
<i>PDISEL</i>	Price of diesel to industrial users in PADD <i>pr</i> in year <i>t</i>	Mapped from <i>PDSTR</i>	\$/gallon
<i>PEN</i>	Price of energy used in the corn to ethanol conversion process in PADD <i>pr</i> in year <i>t</i>	Mapped from <i>PNGIN</i>	\$/MMBtu
<i>PETOH</i>	Delivered price of ethanol produced from crop <i>i</i> in PADD <i>pr</i> in year <i>t</i> for volume step <i>e</i> for quantity of ethanol demand <i>Q</i>	Endogenous Variable	\$/gallon
<i>PETOHRSFACT</i>	Conversion factor to convert prices from \$/gallon to \$/barrel	42 gallons equals one barrel	Gallons/barrel
<i>Q</i>	Delivered quantity of ethanol produced from crop <i>i</i> in PADD <i>pr</i> in year <i>t</i> for volume step <i>e</i> for price of ethanol <i>PETOH</i>	Endogenous Variable	Billion gallons/year
<i>QSRFACT</i>	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
<i>WPETOH</i>	Delivered price of ethanol produced from crop <i>i</i> in Census Region <i>sr</i> in year <i>t</i> for volume step <i>e</i> for quantity of ethanol demand <i>WQETOH</i>	Mapped from <i>PETOH</i> . Read to <i>PEITR</i> variable in <i>WRENEW</i> common block	\$/barrel
<i>WQETOH</i>	Delivered quantity of ethanol produced from crop <i>i</i> in Census Region <i>cr</i> in year <i>t</i> for volume step <i>e</i> for price of ethanol <i>WPETOH</i>	Read to <i>QETTR</i> variable in <i>WRENEW</i> 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 thru 2020. 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. "CO₂ 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. "CO₂ 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. "CO₂ 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 2020. 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, 1997

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:

Stacy MacIntyre
Oil and Gas Analysis Branch
Energy Information Administration
(202) 586-9795

Documentation:

NEMS Documentation Report: *Petroleum Market Model*, 1997

Archive Media and Installation Manual(s):

Archived as part of the NEMS AEO98 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 2020
- 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 4.2
- 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.