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NEMS
International Energy Module

Model Documentation Report

World Oil Market
Petroleum Products Supply and
Oxygenates Supply Components

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International, Economic, and Greenhouse Gases Division
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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS & ACRONYMS

EMF	Energy Modeling Forum
GDP	Gross Domestic Product
IEO	International Energy Outlook
MAM	Macroeconomic Activity Module
NEMS	National Energy Modeling System
OECD	Organization for Economic Cooperation and Development
OGSM	Oil & Gas Supply Module
OMS	Oil Market Simulation model
OPEC	Organization of Petroleum Exporting Countries
OS	Oxygenates Supply
PADD	Petroleum Administration for Defense District
PMM	Petroleum Market Module
PPS	Petroleum Product Supply
ROW	Rest-of-World
SPR	Strategic Petroleum Reserve
WOM	World Oil Market
WOP	World Oil Price
WORLD	World Oil Refining Logistics and Demand Model

PREFACE

The Energy Information Administration (EIA) has developed the National Energy Modeling System (NEMS) to enhance its energy forecasting capabilities and to provide the Department of Energy with a comprehensive framework for analyzing alternative energy futures. NEMS is designed with a multi-level modular structure that represents specific energy supply activities, conversion processes, and demand sectors as a series of self-contained units which are linked by an integrating mechanism. The NEMS International Energy Module (IEM) computes world oil prices, provides a set of crude oil and refined product import alternatives for the U.S., and generates a worldwide oil supply/demand balance for each year of the forecast period. This report is a reference document for energy analysts, model users, and the public that is intended to meet EIA's legal obligation to provide adequate documentation for all statistical and forecast reports *(Public Law 93-275, section 57(b)(1)*. Its purpose is to describe the structure of the IEM. Actual operation of the model is not discussed here.

The report contains four sections summarizing the overall structure of the IEM and its interface with other NEMS modules, mathematical specifications of behavioral relationships, and data sources and estimation methods. Following a general description of the function and rationale of its key components, system and equation level information sufficient to permit independent evaluation of the model's technical details is presented. The major sections of this report are:

- **Model Overview --** This section identifies the analytical issues IEM is intended to address, the general types of activities and relationships it embodies, and its interactions with other NEMS modules.

- **Structure of IEM Components --** This section describes in greater detail the modeling approach adopted for each IEM component, citing theoretical or empirical evidence supporting those choices. The structure of each component is displayed with flow diagrams and fundamental assumptions about behavior or technology are highlighted.

- **Mathematical Specifications --** Model equations for transforming data, representing behavioral or technological relationships, and defining market equilibrium are presented.

- **Variables, Data, and Parameters --** List of model inputs and outputs with definitions, sources, units of measure. Discussion of data sources and procedures for estimating model coefficients. Cross-reference tables orienting users to the model's computer code are also presented.

These sections of the report are followed by appendices that include an IEM model abstract and an annotated copy of the IEM computer code.

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1. MODEL OVERVIEW

A. IEM Design Objectives

The understanding of world oil market issues, especially the forecasting of mid to long term world oil prices, has always been a primary EIA focus. To enhance the capabilities of the NEMS to address international issues and their interaction with U.S. markets, the International Energy Module (IEM) was incorporated into the system. Components of the NEMS IEM accomplish the following:

- Calculate the average world oil price and provide supply curves for five grades of crude oil for import to the United States.

- Calculate the change in the world oil price in response to shifts in U.S. import demands.

- Provide crude oil and petroleum product supply curves with a representation of foreign supply levels and associated costs for U.S. petroleum imports. Calculate shifts in import supply curves as world oil market conditions vary.[1]

- Provide supply curves for U.S. imports of oxygenates (Methyl tertiary butyl ether [MTBE] and methanol).

Three separate components of the IEM have been developed to carry out these functions. The World Oil Market (WOM) component forecasts international crude oil market conditions, including demand, price and supply availability, and the effects of U.S. petroleum market on the world market. The Petroleum Product Supply (PPS) component generates supply curves for petroleum products imported into the United States. These supply curves reflect conditions in the international market, including refinery capacity, transportation costs, and the effects of U.S. demand on world markets. Finally, the Oxygenates Supply (OS) component produces supply curves for U.S. imports of MTBE and methanol.

B. Scope of IEM

The non-U.S. coverage of oil markets is relatively limited with no representation of refined product markets. The IEM supplements these petroleum-only results in terms of both model inputs and outputs by using results from the NEMS Petroleum Market Module (PMM) and generating

[1] In international trade economics, what is called an "import supply curve" in this report is generally referred to as the rest-of-the-world excess supply curve.

import supply curves for crude oil and refined products that are disaggregated by grade and location. The integrated NEMS formulation therefore links the demand for crude oil by refiners with end-use demands for refined products, which are in turn influenced by various measures of economic activity levels. Table 1-1 summarizes the regionality and level of detail of individual IEM components.

The world oil price (WOP) calculated in the WOM submodule is used to adjust exogenously-determined Petroleum Administration for Defense District-level (PADD) import supply curves for crude oil, refined petroleum products, and gasoline blending components (oxygenates). Figure 1-1 presents a map of the United States segregated into PADDs. World crude trade is mapped into five classes that reflect their product yield characteristics in the refinery environment. One class contains the light, low sulfur crude oils that have a relatively high yield of light products (gasoline, distillate, and jet fuel). The second class consists of medium sulfur heavy oils. The remaining classes have high sulfur content and three weight classes - light, heavy, and very heavy. A total of 14 refined product categories are covered, including gasoline blending components (MTBE, methanol, and reformulated gasoline blending stocks for oxygenated blending [RBOB]) and three grades of distillate fuels and two grades of residual fuels based on sulfur content.

While the IEM is intended to be executed as a module of the NEMS system, and utilizing its complete capabilities and features requires a NEMS interface, it is also possible to execute the WOM component of IEM on a stand-alone basis. The WOM forecasts world oil price on the basis of a market clearing given an exogenously specified OPEC output path. In addition to simultaneously forecasting prices and quantities, the WOM submodule can also be used to determine the regional production and consumption levels (and implicit trade patterns) corresponding to a user-specified world oil price path. Sensitivity analyses can be conducted to examine the response of the world oil market to changes in oil price, OPEC production capacity and demand.

To summarize, the model searches for a world oil price compatible with supply-demand equilibrium in each region. Non-OPEC world demand and supply are determined by a set of price-quantity relationships, and in equilibrium the difference between world demand and non-OPEC world supply equals OPEC production. OPEC production is determined by an exogenously specified output path. Output of a price run includes forecasts of the world oil price, OPEC production, world petroleum production and consumption, net imports by region, OPEC revenue, and spare OPEC capacity.

C. Relation to Other NEMS Components

The IEM both uses information from and provides information to other NEMS components. It primarily uses information about U.S. supply and demand balances and provides information about market conditions in the rest of the world. It should be noted, however, that the present focus of the IEM is exclusively on the international oil market. Currently, any interactions between the U.S. and foreign regions in fuels other than oil (for example, coal trade) are modeled in the particular NEMS module that deals with that fuel. Sources of crude oil demand and supply relationships in the IEM are shown in Table 1-2.

For U.S. crude oil supply and demand, the WOM uses forecasts generated by the NEMS Petroleum Market Module (based on supply curves provided by the Oil & Gas Supply Module and demand curves from the end-use demand modules). For other non-OPEC regions, regional oil demand in a given year is determined as a function of the prevailing average world oil price, the current level of regional economic activity, and its own lagged value. Non-OPEC regional oil supply is specified as a function of the world oil price and regional supply in the previous period. The time path of OPEC production may be specified exogenously or calculated endogenously.[2] In addition to these behavioral relationships, regional oil demand and supply values that are determined exogenously include: (1) U.S. Strategic Petroleum Reserve fill rates or drawdown, (2) worldwide commercial stock build or withdrawal, and (3) worldwide statistical discrepancy.

The WOM subcomponent calculates world crude oil prices based on initial estimates of U.S. crude oil supply and demand volumes provided from the PMM. The resulting WOP determines the position of crude oil, refined product, and oxygenates supply curves, which are sent to the PMM to summarize the availability of imports and petroleum product prices for each year of a NEMS forecast. These supply curves are then brought into the PMM to determine the U.S. petroleum supply/demand balance that reflects a least-cost mix of domestic and foreign supplies. The resulting U.S. crude oil supply and demand quantities are then sent back to the WOM component to recalculate the WOP, which is again used to adjust crude oil and petroleum product supply curves. This iterative process continues until the WOP is stable over successive iterations, implying that the crude oil market is equilibrated both in the U.S. and, given U.S. supplies and demands, the world as a whole. Table 1-3 summarizes IEM inputs from and outputs to other NEMS modules.

[2] OPEC behavior can alternatively be represented using a price reaction function relating percentage price changes to capacity utilization rates, with stable prices when target utilization rates are achieved. Although this formulation has been shown to be consistent with observed outcomes, its explanatory power has been greatly improved by also including changes in OPEC production capacity that are compatible with OPEC's market management strategies that attempt to achieve a targeted world oil price within a preferred price band.

Table 1-1. Scope of IEM Components

IEM Component	Regionality	Coverage
WOM/Pricing	U.S	Petroleum Consumption
	U.S. Territories	
	Canada	
	Mexico	
	Western Europe	
	Japan	
	Australia/New Zealand	
	Former Soviet Union	
	Eastern Europe	
	China	
	India	
	South Korea	
	Outer Asia	
	Middle East	
	Africa	
	South and Central America	
	U.S. (50 states)	Petroleum Production
	Canada	
	Mexico	
	Western Europe	
	Japan	
	Australia/New Zealand	
	Former Soviet Union	
	Russia	
	Caspian Area	
	Other FSU	
	Eastern Europe	
	OPEC	
	Asia	
	Middle East	
	North Africa	
	West Africa	
	South America	
	Other Non-OPEC	
	China	
	Other Asia	
	Middle East	
	Africa	
	South and Central America	

Table 1-1 (continued). Scope of IEM Components

IEM Component	Regionality	Coverage
WOM/Pricing	Africa South and Central America	Petroleum Production
WOM/U.S. Imports	PADDs	Crude oil Low Sulfur Light Med. Sulfur Heavy High Sulfur Light High Sulfur Heavy High Sulfur, Very Heavy
PPS	PADDs	Refined Products Reformulated Gasoline Traditional Gasoline No. 2 Heating Oil Low Sulfur Diesel (500 ppm) Low Sulfur Residual Fuel High Sulfur Residual Fuel Jet Fuel Liquefied Petroleum Gases Petrochemical Feedstocks Other Refined Products* Ultra Low Sulfur Diesel (15 ppm) PADD V Reformulated Gasoline Blending Stocks for Oxygenated Blending (RBOB)
OS	PADDs	Oxygenates Methanol MTBE

* Includes refinery gas, naphtha, petroleum coke, and other miscellaneous products.

Table 1-2. Sources of Crude Oil Demand and Supply

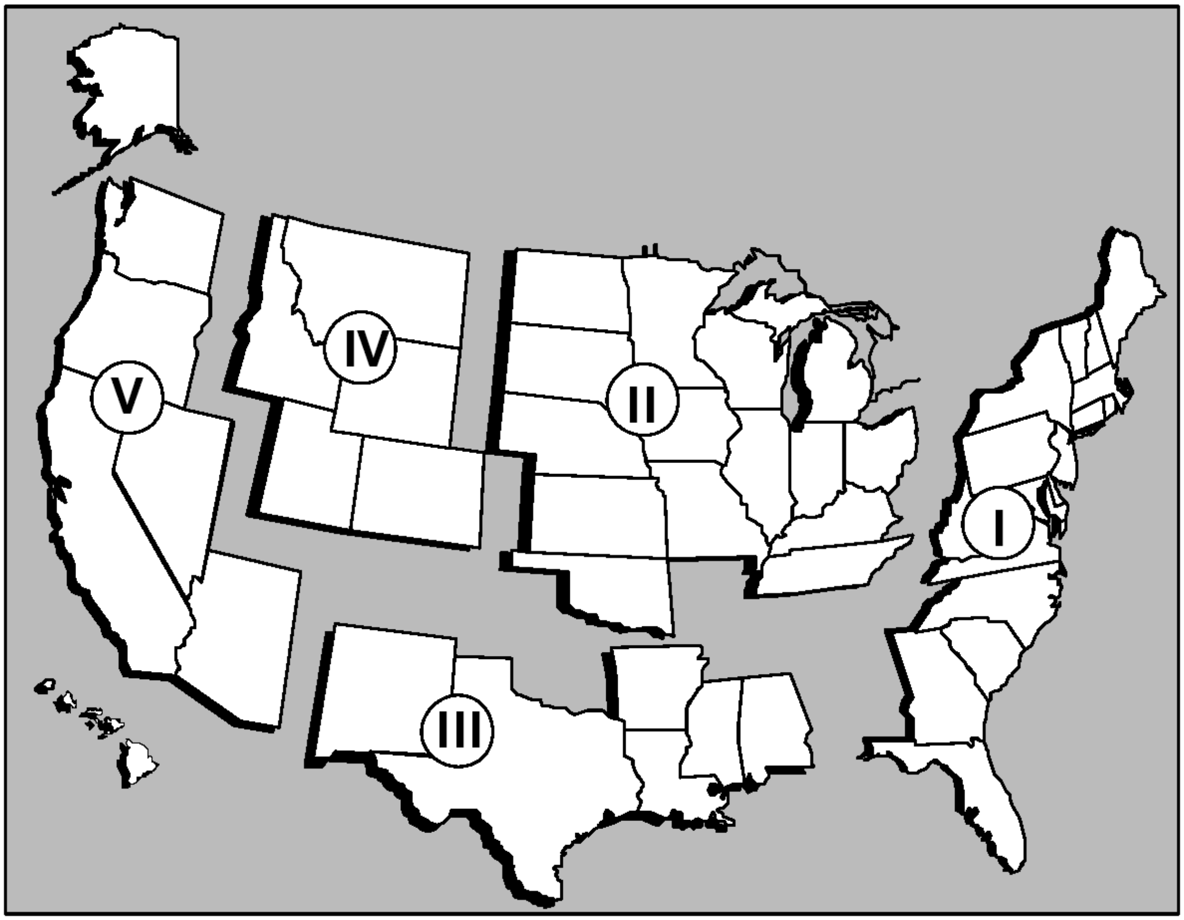
	Crude Oil Demand	Crude Oil Supply
U.S.	NEMS PMM	NEMS PMM
Other Non-OPEC	Endogenous	Endogenous
OPEC	Not Applicable	Optional

Table 1-3. Intermodule Input and Output Flows for the International Energy Module

Model Inputs	From Module	Regions
Controlling information: iteration count, time horizon, etc.	System	Not Applicable
U.S. Petroleum supply and demand	PMM	U.S.
U.S. Gross Domestic Product	MAM	U.S.

Model Outputs	To Module	Regions
World oil price	System	Not Applicable
Import supply curves for crude oil by grade	PMM	PADD
Import supply curves for refined products	PMM	PADD
Import supply curves for gasoline blending components (oxygenates)	PMM	PADD

Figure 1-1. Petroleum Allocation for Defense Districts Map



2. STRUCTURE OF IEM COMPONENTS

2.1 World Oil Market

A. Background

The purpose of the World Oil Market component of IEM is to compute the prices and available quantities of crude oil for import to the U.S. under alternative worldwide energy market conditions over the 1990-2025 time period. Alternative scenarios could include policy and regulatory initiatives (such as foreign adoption of U.S. clean air standards), resource conditions (such as the declining quality of crude oil in world trade or the location of new refinery capacity), and economic growth paths (such as low, mid, and high cases).

Prior to the NEMS, *Annual Energy Outlook* forecasts have not typically contained any formal feedback mechanism between world oil price estimates and U.S. petroleum consumption and imports. World oil price trajectories have been treated simply as unalterable assumptions in each scenario. Now world oil prices are endogenously determined as a function of NEMS-determined oil supply and demand, introducing formal feedback effects to world and U.S. economic growth.

B. General WOM Modeling Approach

The World Oil Market (WOM) submodule adopts the basic methodology of an earlier EIA oil market forecasting tool, the Oil Market Simulation (OMS) model. However, the WOM submodule is able to achieve more detailed coverage of U.S. supply and demand patterns provided through linkages with the NEMS Petroleum Market Module (PMM). The OMS model used a recursive simulation approach in which period $t+1$ values of endogenous variables such as oil demand and supply levels are influenced by their values in period t. Implementing this approach involves three key components of global crude oil markets: demand, non-OPEC oil supply, and OPEC production. Here the behavior and decision rules of economic agents in the oil market which determine these factors is discussed.

Crude Oil Demand:

U.S. crude oil demand is provided to the WOM submodule by the PMM, and is therefore exogenous to the WOM. The demand for crude oil in each non-U.S. region is endogenously determined within the WOM submodule by three factors: real income, world oil price, and demand for crude oil in the previous period. Traditional economic theory and empirical findings have shown that both income and price play an important role in determining oil consumption; income has a positive impact on demand and price has a negative impact. Price changes influence demand both directly and indirectly through their impact on levels of economic activity. The demand for oil in a previous year is called lagged demand, and is used to capture the demand adjustment process reflected in varying short-run and long-run price elasticities. Short-run demand is considered less elastic than long-run demand because the demand for petroleum products is derived from the demand for the services of energy-using capital or other end-use durables, such as automobiles, aircraft, and electric appliances. Delays in altering this energy-using capital stock limit the extent to which consumers are able to change their levels of energy consumption in the short-run. Therefore, the inclusion of lagged variables in the oil demand equation assumes that consumption will slowly adjust over time in response to a one-time change in prices, *ceteris paribus*, until a new level of demand is reached which is consistent with the new structure of relative prices.

Non-OPEC Oil Supply:

U.S. crude oil production is also provided to the WOM submodule by the PMM. The supply of oil from other non-OPEC regions is determined by two factors: world oil price and non-OPEC production lagged one period. Crude oil production within each region is divided into conventional and unconventional sources, with distinct supply functions and parameter values for each type of production. Conventional and unconventional supplies are both positively related to world oil prices, subject to an upper bound set by production capacity. The incorporation of lagged production in the supply equations reflects that the supply of oil at any particular time is, in part, determined by supply during the previous period. As with oil demand, short-run supply responses to a change in oil prices is limited by the time required to invest in the new equipment required to expand production capacity (e.g., drilling rigs) and the delays inherent in adding reserves, developing wells, and extracting oil. Therefore, oil supply is more price-elastic in the long-run than in the short-run. Other things being equal, oil producers will adjust over time in response to a discrete change in prices until a new optimal level of supply is reached. Lagged supply can also be thought of as a proxy for information about oil reserves and production capacity.

OPEC Production:

Output and pricing behavior of OPEC in the IEM are exogenously specified by a time path of OPEC production based on expert judgement and/or "offline" analysis. Assumed growth rates of OPEC production may vary from year to year over the forecast period, but the level of OPEC output within any given year is independent of the WOP. (Of course, the converse does not hold since the equilibrium WOP will depend on the specified level of OPEC output.

World Oil Market Interactions:

The WOM submodule of IEM solves for the equilibrium world oil price (WOP) which equates world petroleum demand with the sum of non-OPEC supply and OPEC production. Changes in prices bring the world oil market into balance though three primary channels:

- The direct effect on regional demand due to world prices, where higher prices imply lower consumption and vice-versa.

- The direct effect on non-OPEC production, where a higher price stimulates increased output, all else held constant.

- The indirect effect of price on consumption as it alters real income growth (the feedback effect), with higher oil prices reducing real income which, in turn, implies lower consumption since the consumption/income effect is positive, although generally inelastic.

The parameters in the non-OPEC oil demand and supply equations are estimated on the basis of forecasts from other larger models. This approach is adopted because the OMS is designed to forecast future activities in the world oil market. Models providing various inputs to the OMS model include the Short-Term Integrated Forecasting System (STIFS), the World Energy Projection System (WEPS), and the Global Insight (formerly Data Resources Incorporated) Macro Model. Details about the derivation of WOM parameter values are discussed in Section 4 of this report.

Crude Oil Import Supply Curves:

The equilibrium world oil price is input directly into the NEMS System module and indirectly to the NEMS PMM in the form of crude oil import supply curves, distinguished by PADD and crude oil quality as outlined in Table 2-1. Because foreign regions are represented in the IEM only as aggregate estimates of petroleum supply and demand (making no distinction as to crude oil, natural gas liquids, refined products, etc.), foreign sources of crude oil to the U.S. are represented in the form of import supply curves. A library of crude oil import supply curves are derived external to NEMS using the WORLD model (see Section 2.2B) as a function of the world oil price, the location and quality of the available world trade crude, world-scale transportation rates and bunker fuel costs, and scenario-specific assumptions. After the WOM has converged, through iterations with related components of NEMS, on a forecasted average world oil price, crude oil import supply curves will be provided to NEMS based on the information in the externally-derived library. The NEMS will be constrained to import a mix of crude oil qualities such that the average acquisition cost to domestic refiners will equal the forecasted world oil price.

Table 2-1. Crude Oil Categories for IEM Import Supply Curves.

Group	Code	Sulfur Content	API Gravity
Low Sulfur Light	S	0-0.2	25-66
		0.2-0.5	32-66
Medium Sulfur Heavy	MH	0.2-1.1	21-32
High Sulfur Light	HL	0.5-1.1	32-56
		1.1-1.3	30-56
		1.3-1.99	35-56
High Sulfur Heavy	HH	1.3-1.99	21-35
High Sulfur Very Heavy	HV	> 0.7	< 21

C. Flow Diagram of WOM Structure

Figure 2-1 shows the general structure of the WOM submodule, including its links with the PPS and OS submodules of IEM. Based on external assumptions and a trial price, crude oil supplies and demands for non-OPEC regions are calculated. U.S. supply and demand is provided from the NEMS PMM (using import supply relationships that are consistent with the trial price), while balances for the rest-of-world (ROW) regions are endogenously estimated using the relationships from Section 3 below.[3] Regional oil production and consumption levels are aggregated to obtain non-OPEC world totals, and any excess of demand over supply is assumed to be met by OPEC production. This "call on OPEC production" is then compared to the exogenously specified level of OPEC output for that period. If required OPEC output is greater than specified OPEC output,

[3] Non-OPEC world regions represented in the IEM are the U.S. (50 States and Territories), Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, India, South Korea, Other Asia, Middle East, Africa, and South and Central America.

there is excess world demand for oil and the current trial price should be raised in the next iteration to dampen demand and stimulate non-OPEC oil production. The new price P'_t is used to adjust the exogenously-derived import supply curves for crude oil and refined products, which in turn induce revisions in U.S. petroleum supply and demand balances. Together with revised ROW crude oil supplies and demands, these adjustments alter the residual demand for OPEC oil. If required OPEC output is under the specified level, the trial price should be lowered to stimulate oil demand and reduce non-OPEC production. This process continues until the demand for OPEC output equals the specified level, indicating that both world and U.S. crude oil markets are in equilibrium at that price.

D. Key WOM Assumptions

The WOM submodule of IEM is based on an approach to modeling international oil markets that is dependent on two key assumptions: 1) oil is the marginal fuel, and 2) OPEC produces such marginal supply at prices that inhibit any significant market penetration of new technologies. Under these assumptions, world oil prices are computed as a function of OPEC production decisions, availability of non-OPEC oil supplies, and worldwide economic growth. Under the assumption that oil is the marginal fuel, competition between oil and other fuels can be ignored since potential volumes of fuel-switching are assumed to be too small to influence prices. The second assumption means the price of oil will not rise high enough to induce the market penetration of new technologies that would reduce the demand for oil sufficiently to put downward pressure on its price.[4] Other assumptions which facilitate the analysis include:

- The current oil price, Gross Domestic Product (GDP) growth rates, and last year's supplies and demands are the only determinants of non-OPEC supply and demand.[5]
- A set of reference supplies and demands (usually specified at a constant real price throughout the forecast period).
- Price-taking behavior by all countries and regions except for OPEC.

[4] Over time conventional oil is expected to gradually decline as the world's marginal fuel. Therefore, accounting for competition among fuels and allowing for the greater possible penetration of new technologies for coal, nuclear power, natural gas and other alternatives will become increasingly important.

[5] This assumption does not apply to the U.S. in the IEM. In order to ensure consistency between World Oil Market results and other components of NEMS, U.S. crude oil supply and demand is taken from the NEMS Petroleum Market Module, which in turn draws inputs from the NEMS Oil & Gas Supply Module.

E. Basis of WOM Modeling Choices

Two distinct approaches are generally used to model the world oil market: recursive simulation and optimization. Both approaches assume that OPEC has significant influence on the world oil price; however, each method assumes a different basis for OPEC behavior. The rationale behind recursive simulation is the perception that there is only limited understanding of past and future energy market behavior. In optimization, OPEC is assumed to set prices in order to maximize the discounted present value of its stream of profits throughout the forecast period. Such an approach implies perfect foresight about future energy markets. That is, OPEC's output decisions are not myopically based only on their influence on current prices and revenue, but instead depend on perfect information about supplies and demands over the entire forecast horizon.[6]

A survey of current models indicates that recursive simulation is favored over optimization. Four advantages of using the recursive simulation approach are frequently cited: 1) it often does well in explaining past data, 2) it evolves from today's actual oil price, 3) forecasts change only gradually in response to parameter changes, and 4) lags can easily be incorporated into the responsiveness of supply and demand. The primary advantage of the optimization approach is that there can be a clearly defined objective for OPEC (e.g., profit maximization) rather than the somewhat *ad hoc* objectives (e.g., target capacity utilization) used in the recursive simulation approach, but this is more than offset by the requirement to assume perfect foresight.

2.2 Petroleum Product Supply

A. Background

The purpose of the PPS component within the IEM is to represent the availability of foreign petroleum product supplies to U.S. markets, so that a least cost mix of domestic and imported supplies can be derived within the PMM. The PPS relies on petroleum product import supply curves obtained from the World Oil Refining, Logistics, and Demand (WORLD) Linear Programming (LP) model, a detailed international refining and transportation model depicting refinery operations, crude oil and refined product trade, and capital expansions and retirements. Since imbedding WORLD directly into the NEMS structure is currently not feasible due to its size and complexity, a set of import supply curves generated from solutions to WORLD are used to summarize global petroleum supply conditions.[7]

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[6] It is important to note that there are as many optimal *ex ante* OPEC revenue streams as there are expectations of future energy market conditions. Any given optimization is driven by a set of foresight assumptions that are highly uncertain.

[7] The possibility of directly incorporating a streamlined or "reduced form" version of WORLD into the IEM has been briefly examined with only limited success.

Only a few international energy models provide forecasts by petroleum product type. However, these models do not simulate the petroleum refining and transportation sectors. By not modeling the refining and transportation sectors of the petroleum industry, these models cannot quantify the impacts on product prices or other factors of interest for policy analyses. They cannot assess the impact, for example, of future refinery construction, significant changes in transportation costs due to requirements for new types of vessels, or new environmental regulations that affect refinery operations or the mix of products consumed.

B. General PPS Modeling Approach

A representation of foreign product supply levels and associated costs are incorporated in the PPS component of the IEM. This representation takes the form of petroleum product supply curves which are obtained from output generated by the WORLD LP model, and subsequently adjusted within the PPS to reflect changes in the world oil price (WOP).[8] These import supply curves consist of a series of three stepped line segments, each defining a single price over a range of supply (Figure 2-2 provides representations of the 2000 import supply curves for motor gasoline and jet fuel to PADD1). PADD-specific import supply curves are generated for each of twelve refined products for each year of a NEMS forecast.

The WORLD LP Model:

WORLD is a 10,000 row by 50,000 column LP model which simulates the operation, technology, and economics of the international petroleum industry. The WORLD model includes numerous cost, technology, demand and logistics components, including detailed refining matrices, and is well-suited for examining the impacts on domestic refiners of environmental regulations, such as reformulated fuel specifications and other policy initiatives. It provides detailed simulations for each year of a NEMS forecast with features such as:

- Crude Oils - provides detail on over 140 world crude oils, by nation and crude type, including SPR crudes;

- Refining Technology - simulates and provides a detailed representation of over 60 refinery processes, including advanced technologies for reformulated gasoline, oxygenates and military fuels;

- Capital Investment - contains factors which represent the cost of capital for refineries in each region;

[8] Again, because foreign regions are represented in the IEM only as aggregate estimates of petroleum supply and demand (making no distinction as to crude oil, natural gas liquids or refined products, for example), it becomes necessary to represent the foreign sources of refined petroleum products to the U.S. in the form of import supply curves.

- <u>Product Formulation and Demand</u> - over 30 product types are represented, and allows product blending and quality specifications to be represented;

- <u>Transportation</u> - provides comprehensive inter-regional transportation detail of crudes, petroleum products, and intermediates;

- <u>Regional Effects</u> - numerous levels of detail are provided, including individual country, crude supply regions (EIA supply regions), refining regions (PADDs) and demand regions (Census Divisions), as well as detail on refinery types.

WORLD is solved by using the above data on crude shipping, processing, investment, blending and product shipping to satisfy specific product demands in a manner which minimizes worldwide refining and transportation costs while simultaneously meeting all system constraints, including shipping limits, capacity and operational limits, product blending specifications, and regional product demands.

Derivation of Import Supply Curves:

The primary output from WORLD to the IEM are the price-quantity arrays used to construct petroleum product import supply curves for each PADD and forecast year of the NEMS. The following steps summarize how the product import supply curves are generated by WORLD for the PPS:

1. Determine maximum refined product imports into the United States by assuming that no additional domestic refinery capacity is built. This is accomplished using the WORLD model for a given year and world oil price case (high, base, or low).

2. The WORLD model simulation in Step 1 represents one piecewise-linear step of an import supply curve for each PADD/refined product combination. Two additional steps of the import supply curves are obtained by reducing U.S. refined product demands in amounts equivalent to one-third of a PADD's import for each refined product and using the WORLD model for each reduced-demand case.

3. The quantities reflected in the import supply curves are the differences between a PADD's import levels in successive simulations of the model. The prices are the marginal prices (shadow costs) from the linear programming solution.

Supply Curve Adjustment:

The fundamental operation conducted within the PPS component is the adjustment of the product import supply curves received from the WORLD model to reflect changes in the estimated world oil price. For a given year of a NEMS forecast, the various components of the IEM iterate with the domestic PMM in NEMS to find a WOP consistent with supply-demand balance in the domestic petroleum markets. The supply curve adjustment process consists of adding or subtracting any change in the WOP to the import product prices after model iteration. The process shifts the import product supply curves up or down by the amount of change in the WOP after each model iteration, but does not alter the shape of the supply curves. Input for this calculation (the WOP) is obtained from the WOM component of the IEM.

The PPS component passes the adjusted product supply curves to the domestic PMM which contains an initial estimate of the quantities of petroleum product and crude imports. The supply levels and costs (the supply curves) of imported products determined within the PPS are then compared to the equivalent U.S. product information in the PMM. That is, the set of product import supply curves, after being adjusted to reflect changes in the WOP, are passed to the PMM and a new U.S. supply and demand balance is achieved in response to the new prices. This iterative process continues until a least cost mix of domestic and foreign supplies is determined.

C. Flow Diagram of PPS Model Structure

Figure 2-3 presents a flow diagram of the PPS Component of the IEM. As can be seen, the WOM component of the IEM provides the world oil price to the PPS which adjusts the import supply curves received from WORLD. This data is then passed to the PMM component of the NEMS which computes a supply/demand balance based on the new set of prices.

D. Key PPS Assumptions

Because of its size and complexity, the WORLD model is currently precluded from being incorporated directly into the NEMS computing environment. Because the petroleum product import supply curves used within the PPS are obtained exogenously, the IEM is not a completely closed system. Incorporating the product import supply curves exogenously implies that the U.S. supply and demand assumptions in the WORLD model will never perfectly correspond to the supply and demand estimates in the IEM and NEMS as a whole. However, such discrepancies have always been found to be insignificant in the mid-term assuming business-as-usual world oil market conditions (that is, conditions under which there are no major disruptions in worldwide petroleum supplies over the forecast period).

E. Basis of PPS Modeling Choices

Models of petroleum product supply that incorporate refinery operation and transportation costs are generally linear programming (LP) models. LPs are the model of choice in the petroleum industry because they allow refiners and distributors to optimize operations given certain production and transportation constraints. In addition, petroleum refining and transportation LPs are the best source of information on marginal costs for individual refined products. Other alternatives involve testing numerous refinery configurations to determine optimal operations before marginal costs can be calculated. The sum of individual petroleum companies' marginal costs becomes the industry supply curve, under the assumption of perfect competition.

LPs yield some measurement of the coproduction phenomenon, one of the most difficult concepts to model in the petroleum industry. In a refinery operation, more than one output is produced at a time. If gasoline is the primary product sought from a refinery run, there will also be coproduction of distillate, jet fuel, and other refined products. Similarly, the production of distillate results in the coproduction of gasoline, jet fuel, and so forth. Isolating marginal costs for any particular fuel in this system of interdependency is difficult without the use of LPs. On the other hand, the disadvantages of LPs include the large quantities of data required to support the model and the amount of computer time needed to solve it.

The key building blocks of the PPS submodule are the supply curves exogenously derived by the WORLD LP model. WORLD is an international refining and transportation LP model, which depicts the economics of worldwide refining and the international trade of crude oils and refined products. In the past, two EIA models have been used to address these issues. However, the refinery formulations of these models failed to adequately simulate the petroleum refining and transportation sectors, and did not appropriately consider environmental regulations or contain adequate structure for assessing potential expansion or retirement of existing worldwide refinery capacity. Consequently, they could not assess the impact, for example, of future refinery construction, significant changes in transportation costs due to requirements for new types of vessels, or new environmental regulations that affect refinery operations or the mix of products consumed.

WORLD can be used to calculate product supply curves under alternative assumptions about the world oil price, changes in refinery operations, and changes in transportation. It allows for additions and retirement of refineries, and changes in their operation and structure. Because of its enhanced capabilities, the WORLD model is now used to generate import supply curves for use in the NEMS. By passing these curves to the domestic PMM component of the NEMS, the PPS modeling choice now allows for an interactive, endogenous determination of the optimal level of U.S. petroleum product imports to be made within the NEMS. Because of its large size and complexity, the WORLD model cannot be directly incorporated into the NEMS.

Due to computer run-time considerations, crude oil, refined product and oxygenate imports into the U.S. are formulated as a set of piece-wise linear import supply curves. It is generally acknowledged that representations of foreign refinery operations would be a superior formulation over the import supply curves. With foreign refinery models in the NEMS, it would be possible to assess such issues as where incremental refinery capacity might be built in the mid to longer term given the stricter environmental specifications of fuels. There has been some experimental efforts to incorporate a reduced-form version of the WORLD model in the NEMS. However, results from these efforts have so far shown only limited potential.

2.3 Oxygenates Supply

A. Background

The purpose of the OS component is to represent the costs of oxygenated fuels available for import into the U.S. The Clean Air Act Amendments of 1990 (CAA90) impose new environmental requirements on some energy sectors. One section of the law requires an increase in the oxygen content of gasoline to reduce carbon monoxide emissions, which can be accomplished by blending with oxygenates. Effective November 1992, gasoline sold in many areas of the United States during the winter must contain a minimum level (2.7 percent by weight) of oxygen. In 1995, "reformulated gasoline" requirements become effective year-round in nine urban areas. Reformulated gasoline is designed to reduce smog formation and requires a minimum oxygen level (2.0 percent by weight) in addition to other component specifications. These new requirements will increase U.S. demand for oxygenates, but the quantity of future demand is uncertain.Several alcohols and ethers can serve as oxygenates, but the ones most commonly used are ethanol and methyl tertiary butyl ether (MTBE). Methanol is also classified as an oxygenate, but it is not expected to be used directly for gasoline blending. However, it is important as a feedstock for the production of MTBE.

It should also be noted that while its environmental properties are an important determinant in the demand for MTBE, MTBE is primarily used as an additive to boost octane content, in unleaded gasolines. In this context, while U.S. lead reduction levels are largely complete, efforts in Western Europe are ongoing, and are just beginning in many other countries of the world. Consequently, the growing demand for oxygenates in the U.S., coupled with the lead reduction programs in other countries, will increase the worldwide demand for MTBE. It is unlikely that domestic production of MTBE will be sufficient to meet the growing U.S. demand, so imports will become an increasingly important source of supply.

B. General OS Modeling Approach

The OS component of the IEM provides import supply curves for methanol and MTBE. These supply curves represent the prices associated with given quantities of methanol and MTBE that are available for import to the United States from foreign sources. The curves are developed and obtained from the WORLD LP model. Within WORLD the curves are developed from data on pricing practices for current production capacity and assumptions about pricing for new production capacity that is under construction or expected to be constructed in the future. Figure 2-4 presents an example of methanol import supply curves to PADD1 over alternative time periods.

These supply curves are used in the OS component in the same manner as described for the petroleum product supply curves in the preceding section. First, the oxygenate supply curves received from the WORLD model are adjusted to reflect changes in the WOP. These supply curves are then passed to the PMM component, where a new supply and demand balance is achieved. (The

WOP is obtained from the WOM component within the IEM). Second, the new quantities of U.S. MTBE and methanol from the PMM component imply a new WOP. The OS component again adjusts the set of oxygenate supply curves based on the new WOP calculated within the WOM. This interaction between the OS, WOM and the PMM is continued until a least cost mix of domestic and foreign oxygenates is obtained. That is, convergence is established when the import quantities (or prices) calculated in the current iteration are identical to the quantities from the prior iteration.

C. Flow Diagram of PPS OS Model Structure

Figure 2-5 presents a flow diagram of the OS component of the IEM. As can be seen the WOM component provides the world oil price to the OS which adjusts the oxygenate import supply curves received from the WORLD LP. These adjusted curves are then passed to the PMM, and through iteration with the WOM, the PMM calculates new input prices and achieves a new U.S. supply-demand balance.

D. Key OS Assumptions

The transportation demand module within NEMS forecasts total demand for high oxygen gasoline. The PMM will determine the quantity of oxygenates needed to satisfy that gasoline demand. The two oxygenates modeled within the OS component, MTBE and methanol, are treated as being competitive, and the PMM determines the demand for each separately.

Because of the expansion potential for the U.S. ethanol industry and the lack of commercial markets for other oxygenates, it is assumed that ethanol, ethyl tertiary butyl ether (ETBE), tertiary amyl methyl ether (TAME), and tertiary butyl alcohol (TBA) will all be supplied from domestic sources. The demand for these oxygenates is not expected to exceed domestic supply capabilities and foreign supplies are not expected to be widely available or less expensive than domestic supplies. Therefore, the IEM does not provide import supply curves for these oxygenates.

E. Basis of OS Modeling Choices

The basis for modeling the OS component corresponds exactly to those for the PPS component. That is, WORLD can be used to calculate oxygenate supply curves under alternative assumptions about the world oil price, changes in refinery operations, changes in transportation costs and requirements, and environmental regulations. It allows for additions and retirement of refineries, and changes in their operation and structure. Because of its highly detailed nature, oxygenate import supply curves are now generated by the WORLD model for use in the NEMS. By passing these curves to the domestic PMM component of the NEMS, the OS modeling choice allows for an interactive, endogenous determination of the optimal level of U.S. petroleum product imports to be made within the NEMS.

Figure 2-1. Flow Chart for IEM Module: Market Clearing with Exogenous OPEC Supply

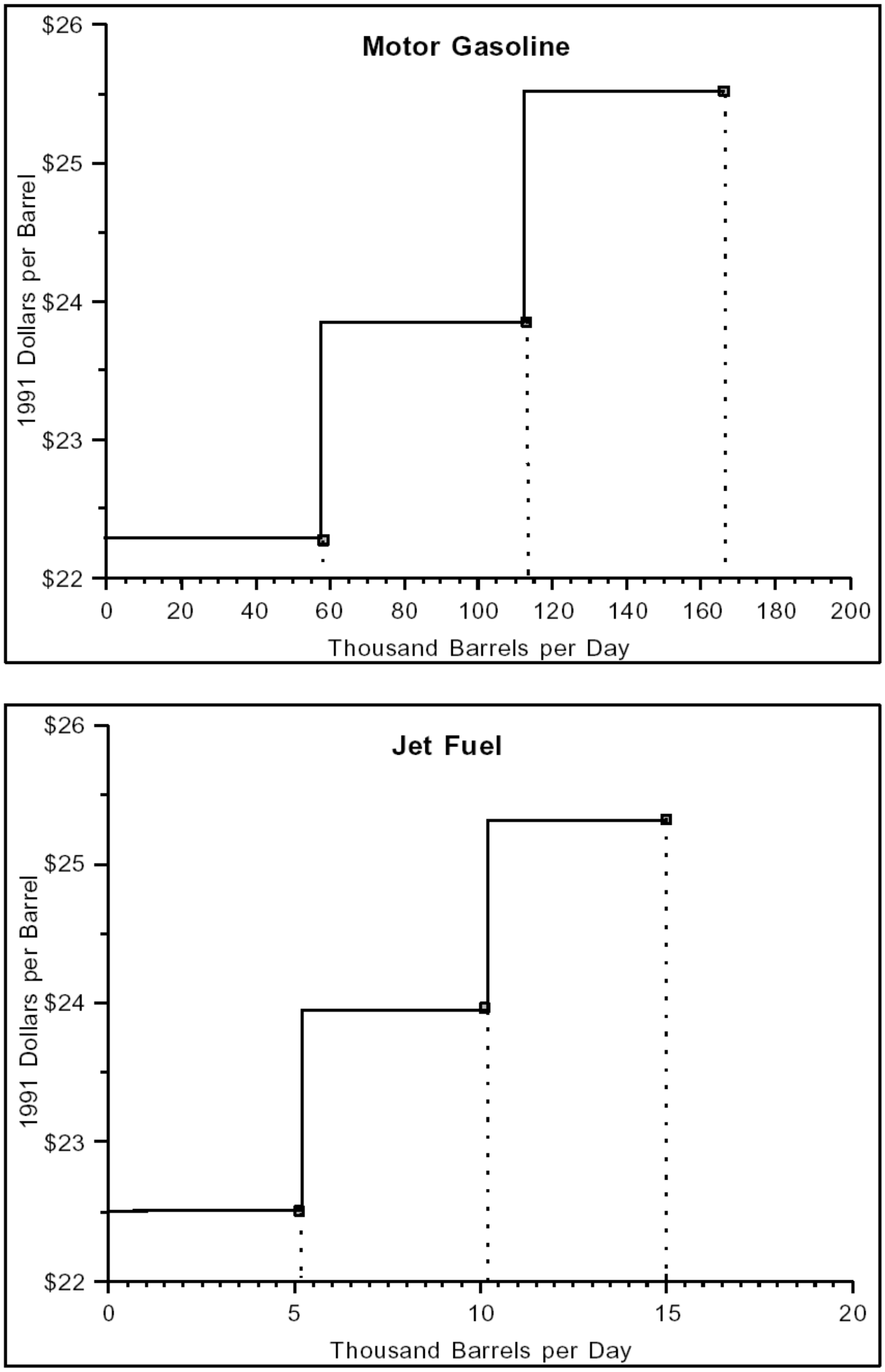


Figure 2-2. 1993 Motor Gasoline and Jet Fuel Import Supply Curves to PADD 1

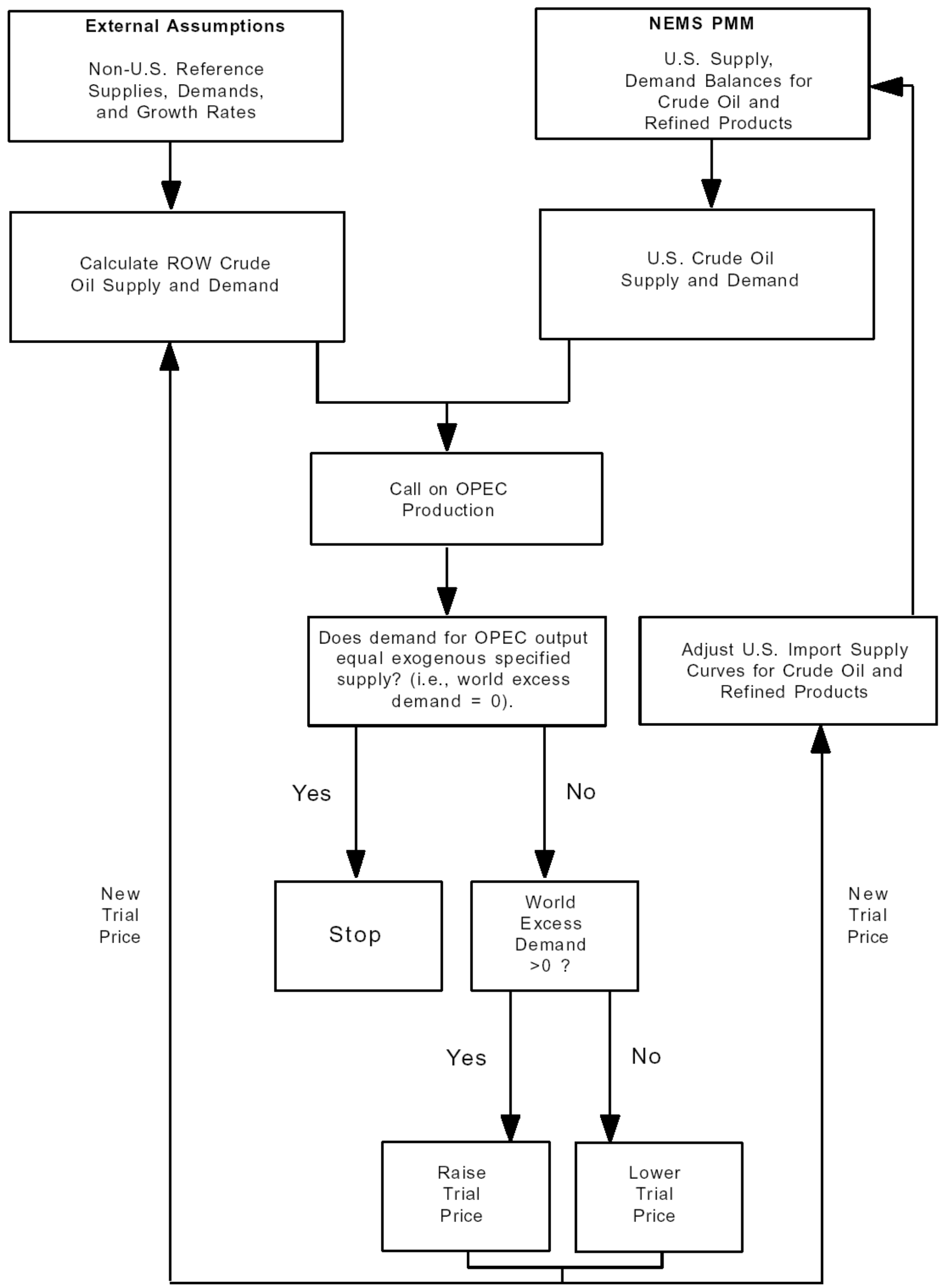


Figure 2-3. Flow Chart for Petroleum Product Supply Submodule

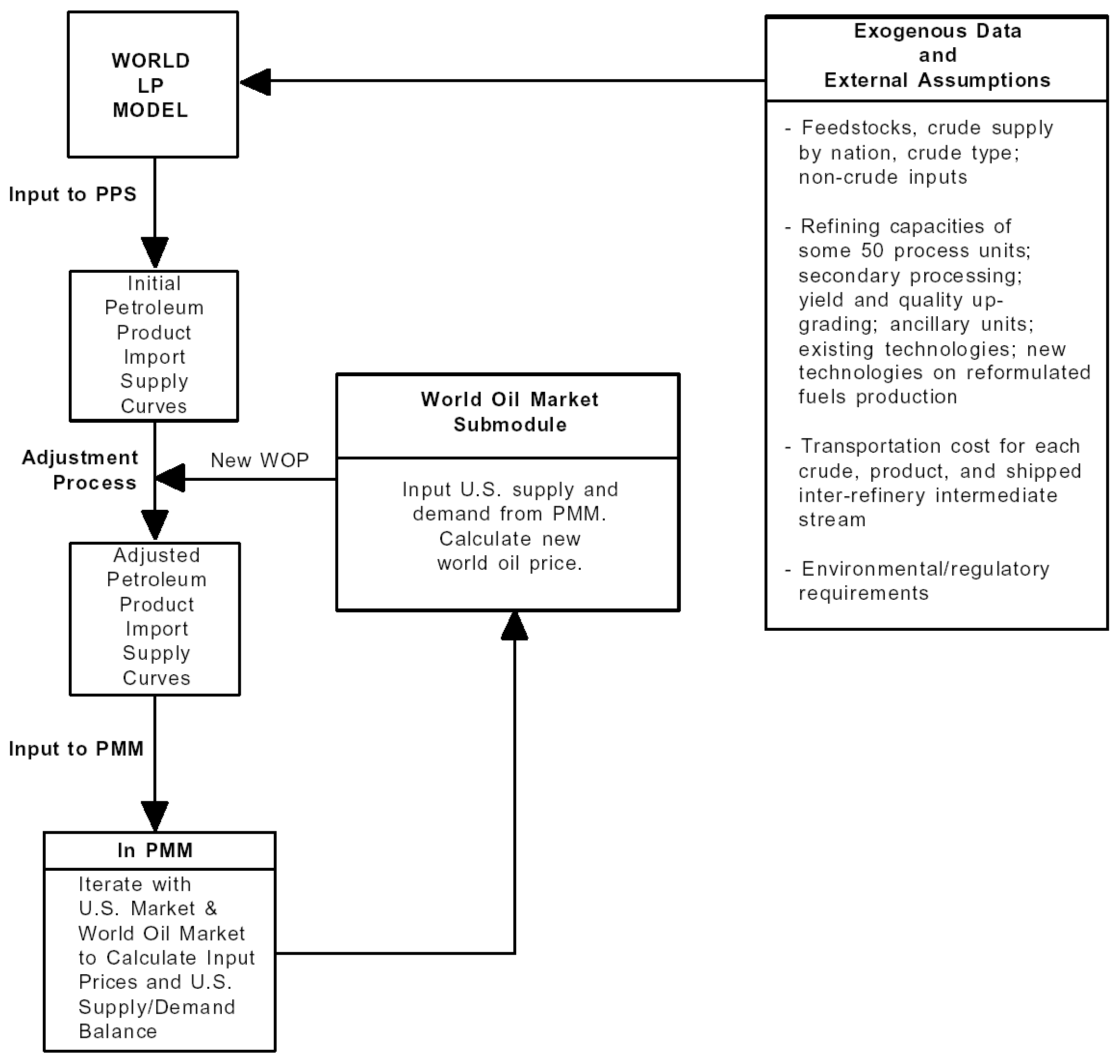


Figure 2-4. Methanol Import Supply Curves to PADD I, 1995, 2000, and 2005

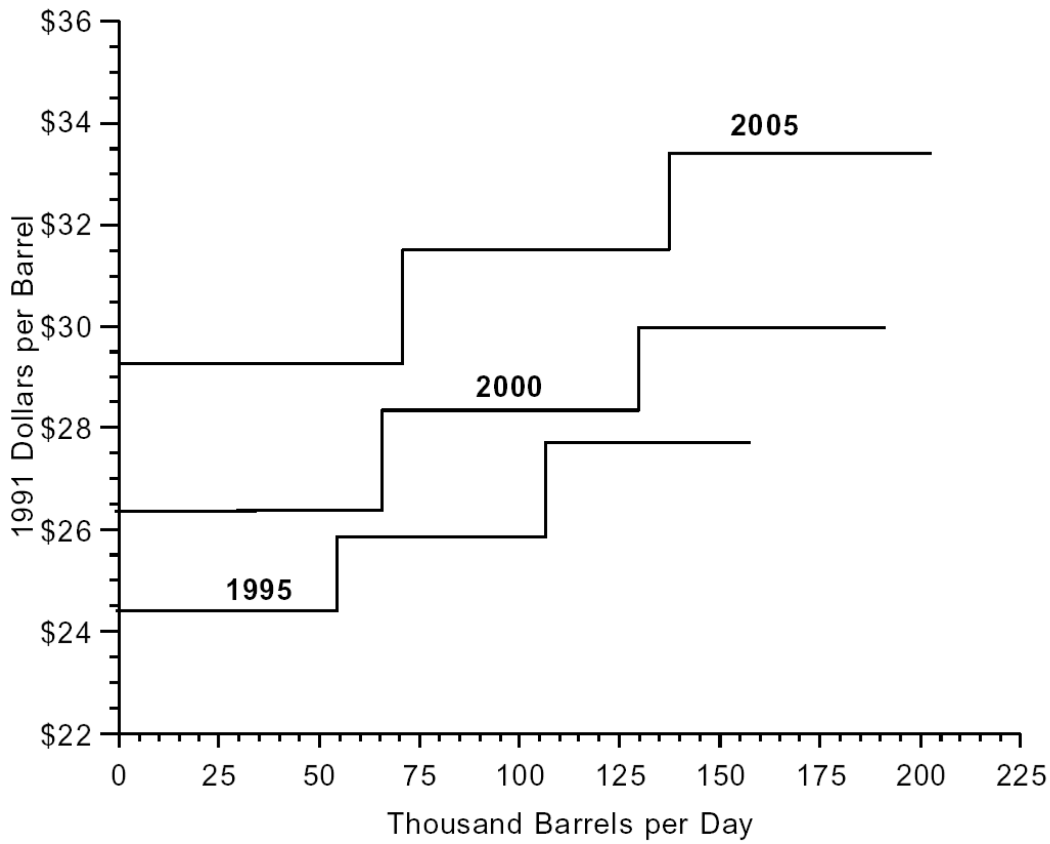
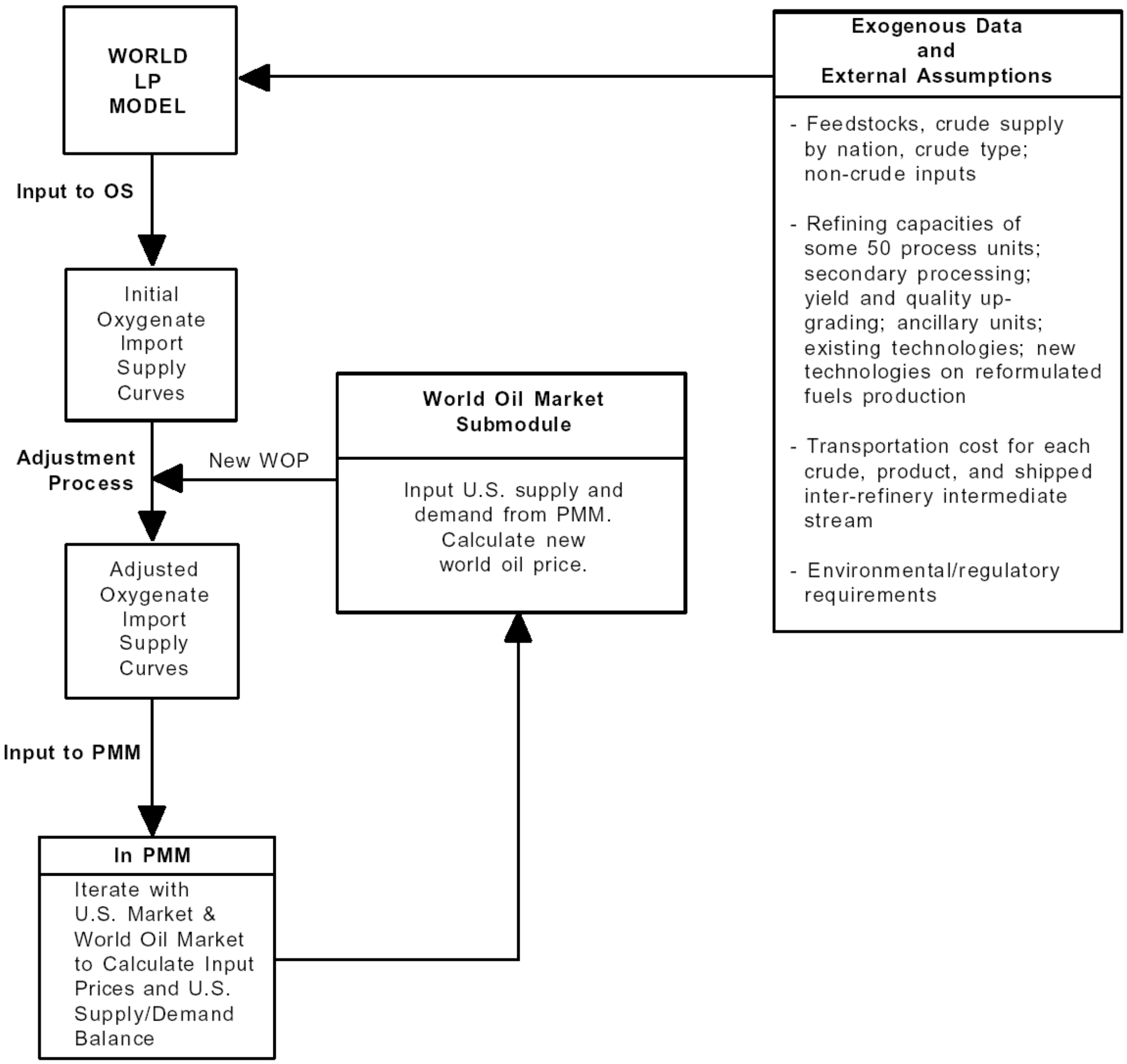


Figure 2-5. Flow Chart for Oxygenates Supply Submodule



3. MATHEMATICAL SPECIFICATIONS

A. World Oil Market

Crude Oil Demand:

U.S. crude oil demand is calculated within the PMM, while crude oil demand for other world regions is estimated using the following functional forms:

$$(1) \qquad D_{i,t} = RD_{i,t} \times \frac{(GDP_{i,t}/RDGP_{i,t})^{y_i}(D_{i,t-1}/RD_{i,t-1})^{a_i}(P_t/RP_t)^{b_i+f_iy_i}}{(GDP_{i,t-1}/RGDP_{i,t-1})^{a_iy_i}(P_{t-1}/RP_{t-1})^{a_if_iy_i}}$$

where the prefix R denotes reference values and

i	=	U.S., U.S. Territories, Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, India, South Korea, Other Asia, Middle East, Africa, South and Central America
D	=	oil demand
GDP	=	gross domestic product
P	=	oil price
t	=	forecast year
y	=	income elasticity
a	=	geometric Koyck-lag parameter
b	=	price elasticity
f	=	feedback elasticity

All parameters and variables except for the oil price P are region specific in all equations for non-OPEC oil demand and supply, although common parameter value assumptions may be adopted for all regions or a subset of regions. Note that the composite price coefficient b + fy reflects that the demand impact of price changes occurs through two channels. The coefficient b represents the usual substitution and income effects resulting in movement along a demand curve in traditional microeconomic theory. The coefficient f reflects the feedback effect arising because higher prices also reduce income, and multiplying this by the income elasticity to obtain the product fy captures the effect of income feedbacks on prices.[9]

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[9] See Section 2.1B and "The Oil Market Simulation Model: Model Documentation Report" (System Sciences, Inc. for EIA, 1985) for further details on the model specification.

Non-OPEC Crude Oil Supply:

Total crude oil supply is divided into conventional and unconventional output, with distinct parameter values in the supply functions for each type of production. U.S. crude oil supply is calculated within the PMM (based on supply curves constructed within the Oil and Gas Supply Module), while crude supply for other regions is estimated using the following functional forms:

$$(2a) \qquad S^c_{i,t} = RS^c_{i,t} \times (S^c_{i,t-1}/RS^c_{i,t-1})^{d_i} \times (P_t/RP_t)^{e_i}$$

$$(2b) \qquad S^u_{i,t} = RS^u_{i,t} \times (S^u_{i,t-1}/RS^u_{i,t-1})^{g_i} \times (P_t/RP_t)^{h_i}$$

$$(2c) \qquad S_{i,t} = S^c_{i,t} + S^u_{i,t}$$

where R, P, and t are defined as before and

i	=	U.S., Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, Other Asia, Middle East, Africa, South and Central America
S^c	=	conventional oil supplies (includes crude oil, natural gas liquids, other liquids, and refinery processing gain)
S^u	=	unconventional oil supplies (includes extraction from oil sands, ultra-heavy oils, shale oil, gas-to-liquids, and coal-to-liquids)
S	=	total non-OPEC liquids supply
d	=	geometric Koyck-lag conventional supply parameter
g	=	geometric Koyck-lag unconventional supply parameter
e	=	price elasticity of conventional supply
h	=	price elasticity of unconventional supply

Oil Market Equilibrium:

Equilibrium in the world market for crude oil requires that world oil demand equal the sum of supplies from non-OPEC conventional sources, non-OPEC unconventional sources, and OPEC production:

$$(3) \qquad \sum_i D_{i,t} + \Delta\, Stock_t = \sum_i S_{i,t} + OPEC_t + Disc_t$$

where D and S are defined as before and

$OPEC_t$ = OPEC production
ΔStock = change in oil inventories (> 0 implies stock build)
Disc = residual term

Crude Oil Import Supply Curve Adjustment:

Output from the WOM submodule is linked to the PMM via a set of crude oil import supply curves, which are externally derived from the WORLD LP model based on an assumed initial oil price. Crude oil import supply curves are distinguished by crude oil grade (see Table 2-1) and PADD location. In order to reflect changes in the WOP forecasted by the IEM, the price associated with each import supply quantity is adjusted by the difference between the current equilibrium price and its initial value:

$$(4) \qquad IMCRSC_{i,j,t} = (IMCRSC_{i,j,t} + Offset) \; / \; Deflator$$

where t is defined as before, and

IMCRSC	=	price component of the imported crude oil supply curve
i	=	crude oil grade
j	=	PADD
Offset	=	the difference between the NEMS forecasted price and the initial price derived by the WORLD model
Deflator	=	GDP price deflator used for adjusting IEM prices to some other year's real prices used by other modules within the NEMS.

B. Petroleum Product Supply

Petroleum Product Import Supply Curve Adjustment:

Within the PPS component of the IEM, petroleum product import supply curves are adjusted to reflect changes in the WOP during each iteration of the model until equilibrium supply-demand conditions are met. The adjustment process shifts import product supply curves up or down, but does not alter their shape (slope) after each iteration of the model. For example, if the WOP increases during model iteration to reflect new supply-demand conditions, this price increase is fully added to the product supply curves. This process is done for each of ten refined products for each of five PADDs, and for each year of the model forecast. Refined product import supply curves are adjusted in the following manner within the PPS:

$$(5) \qquad IMPPSC_{i,j,t} = (IMPPSC_{i,j,t} + Offset) \ / \ Deflator$$

where t is defined as before, and

IMPPSC	=	price component of the imported refined product supply curve
i	=	refined product type
j	=	PADD
Offset	=	the difference between the NEMS forecasted price and the initial price derived by the WORLD model
Deflator	=	GDP price deflator used for adjusting IEM prices to some other year's real prices used by other modules within the NEMS.

C. Oxygenates Supply

Methanol and MTBE Import Supply Curve Adjustment:

Within the OS component, methanol and MTBE import supply curves are adjusted to reflect changes in the forecasted WOP during each iteration of the IEM in the same manner as refined petroleum products are adjusted within the PPS. The adjustment process for oxygenates shifts these curves up (or down), but does not alter their shape. For example, if the current WOP increases, this price increase is fully added to the oxygenate supply curves. This process is done for methanol and MTBE for each of five PADDs, and for each year forecasted. The adjusted oxygenate import supply curves are calculated in the following manner within the OS:

$$(6) \qquad IMOXSC_{i,j,t} = (IMOXSC_{i,j,t} + Offset) \ / \ Deflator$$

where t is defined as before, and

IMOXSC	=	price component of the imported oxygenates supply curve
i	=	oxygenate type
j	=	PADD
Offset	=	the difference between the NEMS forecasted price and the initial price derived by the WORLD model
Deflator	=	GDP price deflator used for adjusting IEM prices to some other year's real prices used by other modules within the NEMS.

D. Solution Methodology

The WOM module projects annual world oil prices and associated worldwide petroleum supply/demand balances. The solution algorithm in the model solves for the price at which the demand for OPEC oil (total demand less non-OPEC supply) intersects either the exogenously specified OPEC production path or the price-reaction function. A standard iterating procedure, the Newton-Raphson algorithm, is used to search for a price P* at which total demand $D = f(P)$ less non-OPEC supply $S = g(P)$ equals the level of OPEC output X.[10] The level of OPEC output can be determined from either the exogenously specified production path or the inverse $X = h^{-1}(P)$ of the price reaction function.

The starting point for the algorithm is a set of reference quantities and prices. The reference price path is a projection that assumes prices remain constant in real terms throughout the forecast period. The reference quantities are derived using equations in the OMS model as a function of this assumed reference price path. These resulting reference values are projections of oil supply and demand that are consistent with historically observed quantities, world oil prices, GDP levels, and exchange rates. Each iteration gets closer to the solution, by adjusting the current estimate of the solution price up or down. It stops searching when the next adjustment to the price would be less than one-half cent.

Solution Method for Price Run:

The sequence of steps for obtaining an WOM price run solution is:

(a) User provides period t-1 historical values and reference paths of oil demand, supply, and GDP for each region.

(b) User provides commercial and strategic inventory supplies as well as an assumed statistical discrepancy.

(c) Based on a trial price, Equations (1) and (2c) are used to compute non-OPEC oil supplies and demands, with (2a) and (2b) substituted into (2c).

(d) The difference between (1) and (2c) equals world excess demand, which is the call on OPEC production.

(e) When an exogenous OPEC output path is specified, the demand for OPEC output from step (d) is compared to that level. If the call on OPEC output is greater (less) than OPEC supply, the trial price is raised (lowered) and steps (a)-(d) are repeated. If the call on OPEC output equals OPEC supply, the world oil market is in equilibrium at that price and the search process stops.

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[10] Such solution techniques are discussed in *Mathematical Applications of Electronic Spreadsheets* by Deanne E. Arganbright (McGraw Hill, 1985). Here f, g, and h refer to functions and are unrelated to the parameters f and g in Section 3A.

Solution Method for Production Run:

The sequence of steps for obtaining an OMS production run solution is:

(a) User provides annual world oil prices over forecast period.

(b) Assumed prices are substituted in Equations (1) and (2) to obtain annual regional non-OPEC production and demand.

(c) User provides OPEC demand and commercial and strategic inventory supplies.

(d) Regional demands are summed to obtain world demand.

(e) Regional production levels are summed to obtain non-OPEC world production.

(f) OPEC production is figured as the difference between world demand and non-OPEC world production, as implied by Equation (3).

4. VARIABLES, DATA, AND PARAMETERS

A. Variable and Parameter Lists

A complete listing of variables and parameters for each of the IEM submodules is provided in Tables 4-1 and 4-2, respectively.

B. WOM Data Sources and Estimation Methods

Estimation of Demand and Supply Functions:

In principle, the parameters of the foreign non-OPEC crude oil demand and supply functions represented by Equations (1), (2a), and (2b) could be estimated in a conventional fashion by applying regression analysis to a set of historically observed data. However, the values of these coefficients should also be consistent with the projections of macroeconomic activity, energy demand and supply, and domestic and international energy prices generated by other forecasting models. Therefore, the relevant oil demand and supply elasticities are derived using the results of simulations of such large-scale energy and macroeconomic models. The foreign-region coefficient estimates are calibrated to simulations of the World Energy Projection System (WEPS) and the Global Insight (formerly Data Resources Incorporated) macroeconomic model.[11] These data sources, including values of U.S. functions in stand-alone mode, are listed in Table 4-3.

C. PPS/OS Data Sources and Estimation Methods

Both the PPS and OS subcomponents of the IEM receive external input data from the WORLD LP model. The PPS receives price and quantity import data for ten refined products for each PADD, while the OS receive methanol and MTBE price and quantity import data for each PADD. These data are used to construct petroleum product and oxygenate import supply curves which are used by the PPM module of the NEMS to derive a supply/demand balance.

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[11] The OMS model, which is the predecessor of the WOM component of the IEM, was formerly operated on a stand-alone basis with U.S. oil demand and supply functions analogous to (1) and (2). The U.S. coefficient estimates of these functions were calibrated to simulations of the Short-term Integrated Forecasting System (STIFS), the Intermediate Future Forecasting System (IFFS), and the Data Resources, Inc. (DRI) macroeconomic model. Since the IEM now receives U.S. supply and demand data from the PMM, equations (1) and (2) no longer apply to the U.S. when the IEM is executed as a component of NEMS. However, the original specification can be retained if it is desired to run the IEM independently of other NEMS modules.

Table 4-1. IEM Model Variables

World Oil Market Component

Variable	Definition	Type
P_t	World Oil Price	Endogenous
$D_{i,t}$	Demand for Oil	Endogenous
$RD_{i,t}$	Reference Demand for Oil	Exogenous
$RS_{i,t}$	Reference Oil Production	Exogenous
$GDP_{i,t}$	Gross National Product	U.S., Endogenous to NEMS (from Macroeconomic Module) Non-U.S., Exogenous
$S_{i,t}$	Total Oil Production	Endogenous
$S_{c,i,t}$	Conventional Oil Production	Endogenous
$S_{u,i,t}$	Unconventional Oil Production	Endogenous
$D_{O,t}$	Demand for OPEC Oil	Endogenous
POPEC	OPEC Oil Production	Endogenous
CU	OPEC Capacity Utilization	Endogenous
Z_t	Percent Change in P_t from P_{t-1}	Endogenous
$Q\_IMCR_{j,k,t}$	Crude Import Quantity Array	Exogenous
$P\_IMCR_{j,k,t}$	Crude Import Price Array	Exogenous
Offset	Difference between current WOP forecast (multiplied by a deflator) and initial oil price (in constant dollars)	Endogenous

Table 4-1. IEM Model Variables (continued)

Petroleum Product Supply & Oxygenate Supply Components

Variable	Definition	Type
P_t	World Oil Price	Endogenous
Offset	Difference between current WOP forecast (multiplied by a price deflator) and initial oil price (in constant dollars)	Endogenous
$IMRGSC_{j,t}$	Reformulated Gasoline Import Supply Curve (price and quantity array)	Exogenous
$IMGSSC_{j,t}$	Traditional Gasoline Import Supply Curve (price and quantity array)	Exogenous
$IMMDSC_{j,t}$	No. 2 Heating Oil Import Supply Curve (price and quantity array)	Exogenous
$IMLDSC_{j,t}$	Low Sulfur Diesel (500 ppm) Import Supply Curve (price and quantity array)	Exogenous
$IMLRSC_{j,t}$	Low Sulfur Residual Fuel Import Supply Curve (price and quantity array)	Exogenous
$IMHRSC_{j,t}$	High Sulfur Residual Fuel Import Supply Curve (price and quantity array)	Exogenous
$IMJFSC_{j,t}$	Jet Fuel Import Supply Curve (price and quantity array)	Exogenous
$IMLPSC_{j,t}$	Liquefied Petroleum Gases Import Supply Curve (price and quantity array)	Exogenous
$IMPFSC_{j,t}$	Petrochemical Feedstock Import Supply Curve (price and quantity array)	Exogenous
$IMOTSC_{j,t}$	Other Refined Products Import Supply Curve (price and quantity array)	Exogenous

Table 4-1. IEM Model Variables (continued)

Variable	Definition	Type
$IMXGSC_{j,t}$	PADD V Reformulated Gasoline Blending Stocks for Oxygenated Blending (RBOB) Import Supply Curve (price and quantity array)	Exogenous
$IMOTSC_{j,t}$	Ultra Low Sulfur Diesel (15 ppm) Import Supply Curve (price and quantity array)	Exogenous
$IMMESC_{j,t}$	Methanol Import Supply Curve (price and quantity array)	Exogenous
$IMMTSC_{j,t}$	MTBE Import Supply Curve (price and quantity array)	Exogenous

Units of measure:

Oil quantities = millions of barrels per day (MMB/D)
Oil prices = real dollars per barrel
Incomes = real dollars
Petroleum product import quantities = millions of barrels
Petroleum product import prices = real dollars per barrel

For all demand-related variables, the subscript t is a time index in annual increments (e.g., t-1 denotes last year), the subscript i distinguishes consumption regions (U.S. [50 States], U.S. Territories, Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, India, South Korea, Other Asia, Middle East, Africa, South and Central America), while the subscript j distinguishes PADDs, and the subscript k denotes products.

For all supply-related variables, the subscript t is a time index in annual increments (e.g., t-1 denotes last year), the subscript i distinguishes production regions (U.S. [50 States], Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Russia, Caspian Area, Other FSU, Eastern Europe, China, Other Asia, Middle East, Africa, South and Central America, OPEC Asia, OPEC Middle East, OPEC North Africa, OPEC West Africa, OPEC South America), while the subscript j distinguishes PADDs, and the subscript k denotes products.

Table 4-2. WOM Model Parameters

For all demand-related parameters, the subscript t is a time index in annual increments (e.g., t-1 denotes last year), the subscript i distinguishes consumption regions (U.S. [50 States], U.S. Territories, Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, India, South Korea, Other Asia, Middle East, Africa, South and Central America).

For all supply-related parameters, the subscript t is a time index in annual increments (e.g., t-1 denotes last year), the subscript i distinguishes production regions (U.S. [50 States], Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Russia, Caspian Area, Other FSU, Eastern Europe, China, Other Asia, Middle East, Africa, South and Central America, OPEC Asia, OPEC Middle East, OPEC North Africa, OPEC West Africa, OPEC South America).

Parameter	Definition
Demand Functions:	
b_i	Price elasticity of oil demand
y_i	Income elasticity of oil demand
a_i	Koyck-lag demand parameter
f_i	Demand feedback elasticity
Supply Functions:	
e_i	Price elasticity for conventional oil supply
h_i	Price elasticity for unconventional oil supply
d_i	Koyck-lag parameter for conventional supply
g_i	Koyck-lag parameter for unconventional supply
i, j	Parameters of OPEC price reaction function

See "The Oil Market Simulation Model: Model Documentation Report" (System Sciences, Inc. for EIA, 1985) for details on parameter definitions and values.

Table 4-3. Data Sources for Estimated WOM Parameters

- Short-Term Integrated Forecasting System (STIFS)

The STIFS short-term energy balance projections underlying Annual Energy Outlook near-term forecasts are the source of implied short-term (one-year) elasticities of crude oil demand with respect to price, holding all other demand determinants constant.

- The National Energy Modeling System (NEMS)

NEMS produces domestic energy balances for low, mid, and high world oil price scenarios and, for the mid-price trajectory, both high and low income runs to evaluate sensitivities to variation in income. The three price and two income scenarios provide domestic oil supply/demand and one-year price and income elasticities of demand.

- The World Energy Projection System (WEPS)

The WEPS outputs for the *International Energy Outlook* are also based on three price and two income sensitivity cases. Mid- to long-term price/income sensitivities of demand were obtained for Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Former Soviet Union, Eastern Europe, China, India, South Korea, Other Asia, Middle East, Africa, South and Central America. Supply elasticities were also obtained for Canada, Mexico, Western Europe, Japan, Australia and New Zealand, Russia, Caspian Area, Other FSU, Eastern Europe, China, Other Asia, Middle East, Africa, South and Central America, OPEC Asia, OPEC Middle East, OPEC North Africa, OPEC West Africa, OPEC South America.

- The Global Insight (formerly Data Resources Incorporated) Domestic and International Macroeconomic Activity Models

These models were used to estimate the effects of varying world oil price levels on total economic activity (i.e., energy-economy feedback effects).

Note: In addition to these sources, model users have the discretion to specify alternative elasticities.

APPENDIX A

Generation of Import Supply Curves for Crude Oils, Refined Products, and Oxygenates

The representation of the world oil market in the National Energy Modeling System (NEMS) includes a long-term outlook relating to oil prices, worldwide macroeconomic activity, worldwide oil demand, assumptions concerning the expansion of Organization of Petroleum Exporting Countries (OPEC) oil production capacity, and non-OPEC oil supply. Not included in the world oil market representation in the NEMS is an explicit representation of the worldwide refining industry or the worldwide trade of crude oils and refined products. While an embedded worldwide refinery and transportation methodology was given some consideration during NEMS development, the additional model size, complexity, and data requirements made such an idea impractical.

For comprehensive issues relating to worldwide refining and trade, the Energy Information Administration (EIA) traditionally uses the World Oil Refining, Logistics, and Demand (WORLD) model (see EIA Model Documentation: WORLD Reference Manual, DOE/EIA-M058, March 14, 1994, Version 1.1). The WORLD model is a large-scale linear programming formulation of the world oil market. Since the levels and composition of petroleum imports to the United States has always been a critical area of interest, the decision was made to use the robust formulation of the WORLD model for the purpose of generating import supply curves for crude oils, refined products, and oxygenates. A library of import supply curves are derived external to the NEMS using the WORLD model. Each point on a supply curve is a function of year, world oil price, type of import, import level, and destination of import. Each point on a supply curve represents a complete run of the WORLD model. Over 1400 WORLD model runs are required to generate a complete set of import supply curves.

The intent of the generation of supply curves is to provide the NEMS with a flexible set of alternatives concerning crude imports versus product imports, import volumes, and import sources. For each import supply curve, a maximum import volume is provided based on analytical judgment. The import volume is segmented into three equal parts that define the three piece-wise linear steps of the import supply curve. For example, if the maximum gasoline import for PADD I is expected to be no greater than 330 thousand barrels per day in 2005, the three levels of import on the three piece-wise linear steps would be 110, 220, and 330 thousand barrels per day. Three runs of the WORLD model yield three unique gasoline prices associated with the three respective import volumes. The gasoline prices are the marginal prices off of the demand balance row for gasoline in PADD I. The import volumes across the three steps are achieved by varying gasoline demand in PADD I. As might be expected, the pressure on the world oil market to produce additional volumes of gasoline for import into PADD I yields a traditional upward-sloping supply curve (see

Figure 2.2). A similar methodology is used for generating the import supply curves for crude oils and oxygenates. All marginal costs are a function of the world oil price, transport costs (either tanker or pipeline), refining costs, and any costs associated with investment (additions to refining or tanker capacity).

An important advantage to using a detailed oil market model such as WORLD is the ability to backtrack once the NEMS has selected a set import supply curves. Using the NEMS selections, it becomes possible to backtrack through the WORLD model simulations in order to identify the sources of imported petroleum to the United States (see Appendix E).

APPENDIX B

Estimation of Demand Equation Coefficients

The parameters of the foreign oil demand function presented by Equation (1) were estimated by applying nonlinear regression analysis to a set of historically observed data for 1970-1997. The parameters to be estimated were a (the demand lag coefficient), b (the price elasticity), f (the feedback elasticity), and y (the income elasticity). In order to explain why nonlinear regression analysis was used it is necessary to briefly review the linear regression model.

$$(1) \qquad D_{i,t} = RD_{i,t} \times \frac{(GDP_{i,t}/RDGP_{i,t})^{y_i}\,(D_{i,t-1}/RD_{i,t-1})^{a_i}\,(P_t/RP_t)^{b_i+f_i y_i}}{(GDP_{i,t-1}/RGDP_{i,t-1})^{a_i y_i}\,(P_{t-1}/RP_{t-1})^{a_i f_i y_i}}$$

Linear regression provides estimates and other inferential results for the parameters $\beta = (\beta_1, \beta_2, ..., \beta_p)^T$ in the model

$$Y_n = \beta_1 x_{n1} + \beta_2 x_{n2} + ... + \beta_p x_{np} + Z_n$$

$$= (x_{n1}, ..., x_{np})\beta + Z_n.$$

The random variable Y_n represents the response for case n, n=1,2...,N and has a deterministic part and a stochastic part. The deterministic part, $(x_{n1},...,x_{np})\beta$, depends on the parameters β and upon the predictor or regressor variables x_{np}, p=1,2,...,P. The stochastic part is represented by the random variable Z_n and is a disturbance which perturbs the response for that case. The subscript ^{T} denotes the transpose of a matrix.

The model for N cases can be written Y = XB + Z where Y is the vector of random variables representing the data we may get, X is the NxP matrix of regressor variables, and Z is the vector of random variables representing the disturbances. The deterministic part, XB, is a function of the parameters and the regressor variables and gives the mathematical model or model function for the responses. The nonzero mean for Z_n can be incorporated into the model function so that E[Z] = 0 or E[Y] = XB. XB is then called the expectation function of the regression model. The matrix X is called the derivative matrix because the (n,p)th term is the derivative of the nth row of the expectation function with respect to the pth parameter. For a model to be linear the derivatives with respect to any of the parameters are independent of all the parameters. For a model to be nonlinear at least one of the derivatives of the expectation function with respect to the parameters depends on at least one of the parameters.

If natural logarithms are taken of both sides of equation (1) the equation is as follows:

$$\log(D_{i,t}) = \log(RD_{i,t}) + (y_i * \log(GDP_{i,t}/RGDP_{i,t})) -$$

$$(a_i * y_i * \log(GDP_{i,t-1}/RGDP_{i,t-1})) + (a_i * \log(D_{i,t-1}/RD_{i,t-1})) +$$

$$(((b_i + (f_i * y_i)) * \log(P_{i,t}/RP_{i,t}))-((a_i * f_i * y_i)*\log(P_{i,t-1}/RP_{i,t-1}).$$

Since

$$\partial\log(D_{i,t})/\partial a_i = - (y_i * \log(GDP_{i,t-1}/RGDP_{i,t-1})) + \log(D_{i,t-1}/RD_{i,t-1})) -$$

$$((f_i * y_i) * \log(P_{i,t-1}/RP_{i,t-1}),$$

$$\partial\log(D_{i,t})/\partial b_i = \log(P_{i,t}/RP_{i,t}),$$

$$\partial\log(D_{i,t})/\partial f_i = (y_i * \log(P_{i,t}/RP_{i,t})) - ((a_i * y_i) * \log(P_{i,t-1}/RP_{i,t-1}),$$

and

$$\partial\log(D_{i,t})/\partial y_i = \log(GDP_{i,t}/RGDP_{i,t}) - (a_i * \log(GDP_{i,t-1}/RGDP_{i,t-1})) +$$

$$(f_i * \log(P_{i,t}/RP_{i,t})) - ((a_i * f_i) * \log(P_{i,t-1}/RP_{i,t-1}) ,$$

it is clear that at least one of the derivatives of the expectation function with respect to the parameters depends on at least one of the parameters and that this model is a nonlinear model.

The SAS procedure NLIN (NonLINear regression) was used to estimate the parameters a_i, b_i, f_i, and y_i. The procedure NLIN computes least squares or weighted least squares estimates for the parameters of a nonlinear model. In order to estimate nonlinear parameters using the procedure NLIN one must write the regression expression, declare parameter names, supply starting values for them, and possibly supply derivatives of the model with respect to the parameters. The NLIN procedure first examines the starting value specifications of the parameters. If a grid of values is specified, NLIN evaluates the residual sum of squares for each combination of values to determine the best set of values to start the iterative algorithm.

In the procedure NLIN the system of equations represented by the nonlinear model is

$$Y = F(\beta_o^*,\beta_1^*,...,\beta_r^*,Z_1,Z_2,...,Z_n) + \xi = F(\beta^*) + \xi$$

where Z is a matrix of independent variables, β^* is a vector of the unknown parameters, ξ is the error evctor, and F is a function of the independent variables and the parameters. The are two approaches to solving the minimum. The first approach is to minimize

$L(\beta) = 0.5\, e'e$ where $e = Y - F(\beta)$ and β is an estimate of β^*.

The second method is to sovle the nonlinear "normal" equations

$X'F(\beta) = X'e$ where $X = \partial F/\partial\beta$.

In the nonlinear situation, X and $F(\beta)$ are functions of β and a closed-form solution generally does not exist. As a result, NLIN uses an iterative process where a starting value for β is chosen and continually improved until the error sum of squares $e'e$ ($L(\beta)$) is minimized. The iterative techniques which NLIN uses are similair to a series of linear regressions involving the matrix X evaluated for the current values of β and $e=Y-F(\beta)$ where the residuals are evaluated for the current values of β. The iterative process begins at some point β_0. Then X and Y are used to compute a Δ such that $L(\beta_0+\alpha\Delta)<L(\beta_0)$.

The iterative method used to estimate the parameters a_i, b_i, f_i, and y_i is the modified Gauss-Newton method. The Gauss-Newton method uses the Taylor series

$F(\beta) = F(\beta_0) + F(\beta-\beta_0) + \ldots$ where $X = \partial F/\partial\beta$ is evaluated at $\beta=\beta_0$.

Substituting the first two terms of this series into the normal equations gives

$$X'F(\beta) = X'Y$$

$$X'(F(\beta_0) + X(\beta-\beta_0)) = X'Y$$

$$(X'X)(\beta-\beta_0) = X'Y - X'F(\beta_0)$$

$$(X'X)\Delta = X'e$$

and therefore

$$\Delta = (X'X)^{-1} X'e.$$

A Tukey biweight criterion was also used in the NLIN procedure to improve the estimation results. The weighting function used for the biweight is

$w_i = (1 - (r_i/B)^2)^2$ if $|r_i| \leq B$ or $w_i = 0$ if $|r_i| > B$ where

r is $|\text{residual}|/ó$, ó is a measure of the scale of the error, and B is a tuning constant. The biweight estimator depends on the measure of scale (like the standard deviation) and a tuning constant.

While performing various aspects of the nonlinear regression analysis in all of the regions it was discovered that the feedback elasticity coefficient repeatedly had insignificant t ratios and a high correlation with other parameters, indicating overparameterization. This suggests that the feedback elasticity coefficient could be zero and that a simpler

model may be adequate. However, the value of this coefficient is already close to zero. As a result, the feedback coefficient in all the regions was set to a constant close to zero and then the parameters a_i, b_i, and y_i were then estimated.

APPENDIX C

Sample Input Data for Crude Oil Import Supply Curves

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*                        PADD I   PADD II  PADD III   PADD IV    PADD V
*                        ======   =======  ========   =======    ======
* Year: 2000
* Crude Oil Import Quantities (Step 1)
FLL                       103.9     238.2     403.4      33.2     263.5
FMH                        86.6       5.1     129.9       5.1     234.2
FHL                       267.3     187.6    1334.3      26.0     217.6
FHH                       149.4       5.1     714.5       5.1     201.0
FHV                        45.5       5.1     274.9       5.1      15.0
* Crude Oil Import Prices (Step 1)
FLL                       25.26     24.41     25.62     24.55     24.33
FMH                       23.95     23.03     23.34     22.69     23.83
FHL                       23.90     21.84     23.04     22.09     22.20
FHH                       22.14     22.23     21.97     21.19     21.35
FHV                       19.43     18.17     18.68     18.05     19.54
* Crude Oil Import Quantities (Step 2)
FLL                        97.9     224.5     380.2      31.3     248.5
FMH                        81.7       5.0     122.5       5.0     220.8
FHL                       252.0     176.9    1258.0      24.5     205.3
FHH                       140.9       5.0     673.7       5.0     189.4
FHV                        42.8       5.0     259.2       5.0      14.0
* Crude Oil Import Prices (Step 2)
FLL                       26.37     25.85     26.89     25.95     25.81
FMH                       25.11     23.94     24.66     23.74     24.62
FHL                       24.70     23.01     23.88     22.91     23.32
FHH                       23.16     23.00     23.13     22.43     22.13
FHV                       20.08     19.00     19.74     19.06     20.21
* Crude Oil Import Quantities (Step 3)
FLL                       189.9     217.8     368.8      30.4     240.8
FMH                       158.3       4.9     118.8       4.9     214.2
FHL                       488.7     171.6    1219.8      23.7     198.9
FHH                       273.1       4.9     653.2       4.9     183.9
FHV                        83.2       4.9     251.5       4.9      13.7
* Crude Oil Import Prices (Step 3)
FLL                       27.37     26.63     27.94     26.80     27.21
FMH                       26.47     24.74     26.04     24.82     25.77
FHL                       25.84     24.02     25.00     23.72     24.12
FHH                       24.17     24.03     24.39     23.30     22.88
FHV                       20.96     20.05     20.46     20.08     21.12
* Year: 2005
* Crude Oil Import Quantities (Step 1)
FLL                       106.0     250.9     326.8      35.0     361.9
FMH                        91.2       5.1     136.8       5.1     246.8
```

FHL	319.3	197.7	1705.1	27.4	232.9
FHH	162.0	5.1	773.2	5.1	211.8
FHV	50.2	5.1	301.1	5.1	15.8
* Crude Oil Import Prices (Step 1)					
FLL	21.33	20.27	21.60	20.72	20.48
FMH	19.99	19.06	19.58	18.64	19.07
FHL	18.55	18.05	18.96	17.14	17.69
FHH	16.93	17.39	17.60	17.64	16.60
FHV	14.39	14.12	14.83	13.75	14.86
* Crude Oil Import Quantities (Step 2)					
FLL	99.9	236.5	308.1	32.9	341.4
FMH	86.0	5.0	129.0	5.0	232.6
FHL	301.1	186.3	1607.7	25.8	219.6
FHH	152.7	5.0	729.0	5.0	199.6
FHV	47.3	5.0	283.8	5.0	14.7
* Crude Oil Import Prices (Step 2)					
FLL	21.79	22.41	22.87	21.41	22.26
FMH	21.54	19.99	20.45	19.65	21.06
FHL	20.19	18.63	19.76	18.93	18.30
FHH	18.56	18.75	19.41	17.93	18.08
FHV	16.36	14.35	15.62	15.60	16.54
* Crude Oil Import Quantities (Step 3)					
FLL	250.0	229.4	298.8	32.0	330.9
FMH	200.0	4.9	175.0	4.9	225.7
FHL	583.8	180.8	1558.9	25.0	212.9
FHH	296.1	4.9	706.9	4.9	193.7
FHV	91.7	4.9	275.3	4.9	14.4
* Crude Oil Import Prices (Step 3)					
FLL	23.56	23.18	24.04	22.67	23.01
FMH	22.41	21.03	22.01	20.59	21.98
FHL	21.74	20.01	20.43	20.41	19.77
FHH	20.43	19.75	20.44	18.96	19.60
FHV	17.59	15.99	16.57	16.18	17.84
* Year: 2010					
* Crude Oil Import Quantities (Step 1)					
FLL	107.3	271.8	359.0	37.9	380.7
FMH	98.8	5.1	148.3	5.1	267.3
FHL	345.9	214.2	1980.6	29.7	252.3
FHH	180.4	5.1	852.4	5.1	229.4
FHV	56.9	5.1	338.5	5.1	17.1
* Crude Oil Import Prices (Step 1)					
FLL	22.26	21.06	21.98	21.54	20.79
FMH	21.00	19.18	20.47	19.97	20.93
FHL	19.76	19.20	19.41	17.76	19.41
FHH	18.05	17.95	19.16	18.13	18.00
FHV	14.73	14.31	15.58	14.53	15.63
* Crude Oil Import Quantities (Step 2)					
FLL	101.2	256.3	338.5	35.7	359.0
FMH	93.2	5.0	139.8	5.0	252.0
FHL	326.2	201.9	1867.4	28.0	237.9
FHH	170.1	5.0	803.8	5.0	216.2
FHV	53.6	5.0	319.1	5.0	15.9

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* Crude Oil Import Prices (Step 2)
FLL                      23.85     23.94     24.08     22.50     24.32
FMH                      21.83     19.95     21.38     20.75     21.41
FHL                      20.85     19.41     19.68     20.59     19.62
FHH                      19.83     19.32     19.76     18.51     18.84
FHV                      17.09     15.04     15.85     15.51     17.54
* Crude Oil Import Quantities (Step 3)
FLL                      240.0     248.5     400.0      34.6     348.2
FMH                      200.0       4.9     170.0       4.9     270.0
FHL                      632.5     195.8    1810.7      27.1     230.6
FHH                      329.7       4.9     779.5       4.9     209.9
FHV                      103.8       4.9     309.5       4.9      15.6
* Crude Oil Import Prices (Step 3)
FLL                      26.17     24.44     25.64     23.97     24.51
FMH                      23.46     21.74     23.87     21.34     22.75
FHL                      22.19     20.70     21.06     21.26     20.68
FHH                      19.86     19.69     20.95     19.38     20.73
FHV                      18.30     16.68     17.05     16.53     17.85
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APPENDIX D

Sample Input Data for Refined Product Import Supply Curves

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*                           PADD I   PADD II  PADD III   PADD IV    PADD V
*                           ======   =======  ========   =======    ======
* Year: 2000
* Refined Product Import Quantities (Step 1)
Reformulated Mogas          101.2       5.1      25.2       5.1       5.1
Traditional Mogas            94.1       5.1       5.1      25.6       5.1
No. 2 Heating Oil            72.6       5.1       5.1      15.2       5.1
L S Diesel (500 ppm)         36.3      20.4     223.8      15.7      30.5
Low Sulfur Fuel Oil          84.2       5.1       5.1       5.1      62.5
High Sulfur Fuel Oil         27.2       5.1     120.3       5.1      47.6
Jet Fuel                     73.9      26.4      27.6      32.7       5.1
Liquefied Pet. Gases         18.0      70.5      42.9       5.1       5.1
Petchem. Feedstocks           5.1      55.3     110.4       5.1       5.1
Other Refined Prod.          12.0       5.1       5.1       5.1       5.1
Methanol                      5.1       5.1       5.1       5.1       5.1
M. T. B. E.                  79.0      32.2      85.6       7.4      79.7
PADD V RBOB                   0.0       0.0       0.0       0.0       5.1
U L S Diesel (15 ppm)        36.2      24.2     229.4      19.1      32.5
* Refined Product Import Prices (Step 1)
Reformulated Mogas          34.36     33.38     32.76     32.93     34.01
Traditional Mogas           30.89     30.43     30.17     30.66     28.21
No. 2 Heating Oil           28.86     27.66     27.58     28.04     27.32
L S Diesel (500 ppm)        31.27     30.59     29.94     30.44     29.72
Low Sulfur Fuel Oil         20.31     19.73     19.95     17.21     19.88
High Sulfur Fuel Oil        18.12     17.63     17.04     13.02     16.37
Jet Fuel                    29.61     28.52     28.33     28.39     28.49
Liquefied Pet. Gases        19.79     18.85     18.69     15.95     18.80
Petchem. Feedstocks         23.79     23.49     23.91     24.46     21.70
Other Refined Prod.         21.63     21.59     21.45     17.95     19.35
Methanol                    29.74     29.00     28.99     29.65     27.23
M. T. B. E.                 42.59     41.89     41.78     42.46     40.04
PADD V RBOB                  0.02      0.04      0.09      0.02     32.06
U L S Diesel (15 ppm)       31.77     31.01     30.39     30.96     30.12
* Refined Product Import Quantities (Step 2)
Reformulated Mogas           95.5       5.0      23.7       5.0       5.0
Traditional Mogas            88.8       5.0       5.0      24.2       5.0
No. 2 Heating Oil            68.5       5.0       5.0      14.4       5.0
L S Diesel (500 ppm)         34.2      19.2     211.0      14.7      28.8
Low Sulfur Fuel Oil          79.3       5.0       5.0       5.0      58.9
High Sulfur Fuel Oil         25.7       5.0     113.4       5.0      44.9
Jet Fuel                     69.7      24.9      26.1      30.8       5.0
Liquefied Pet. Gases         17.7      66.5      40.4       5.0       5.0
Petchem. Feedstocks           5.0      52.1     104.1       5.0       5.0
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Other Refined Prod.	11.8	5.0	5.0	5.0	5.0
Methanol	5.0	5.0	5.0	5.0	5.0
M. T. B. E.	74.4	30.3	80.6	7.0	75.2
PADD V RBOB	0.0	0.0	0.0	0.0	5.0
U L S Diesel (15 ppm)	34.1	22.9	216.3	18.0	30.7
* Refined Product Import Prices (Step 2)					
Reformulated Mogas	36.13	35.43	35.04	34.05	35.66
Traditional Mogas	32.59	31.83	31.76	32.56	30.02
No. 2 Heating Oil	30.45	29.21	29.25	30.12	28.43
L S Diesel (500 ppm)	32.42	31.78	31.49	32.81	31.68
Low Sulfur Fuel Oil	21.78	20.91	21.42	17.94	20.78
High Sulfur Fuel Oil	19.14	18.27	18.35	15.49	17.38
Jet Fuel	31.27	29.79	30.12	29.81	30.60
Liquefied Pet. Gases	20.90	19.96	19.64	17.08	20.33
Petchem. Feedstocks	25.52	24.90	25.12	25.58	23.10
Other Refined Prod.	23.10	22.60	22.70	18.88	19.71
Methanol	31.45	30.54	30.71	31.64	28.78
M. T. B. E.	44.23	43.28	43.53	44.43	41.53
PADD V RBOB	0.10	0.16	0.10	0.13	34.26
U L S Diesel (15 ppm)	32.89	32.25	32.00	33.20	32.22
* Refined Product Import Quantities (Step 3)					
Reformulated Mogas	92.7	4.9	23.0	4.9	4.9
Traditional Mogas	85.9	4.9	4.9	23.3	4.9
No. 2 Heating Oil	66.4	4.9	4.9	13.9	4.9
L S Diesel (500 ppm)	33.2	18.6	204.7	14.4	27.8
Low Sulfur Fuel Oil	77.0	4.9	4.9	4.9	57.1
High Sulfur Fuel Oil	24.9	4.9	110.0	4.9	43.6
Jet Fuel	67.6	24.2	25.2	29.8	4.9
Liquefied Pet. Gases	17.3	64.5	39.3	4.9	4.9
Petchem. Feedstocks	4.9	50.6	100.9	4.9	4.9
Other Refined Prod.	11.6	4.9	4.9	4.9	4.9
Methanol	4.9	4.9	4.9	4.9	4.9
M. T. B. E.	72.2	29.5	78.2	6.7	72.9
PADD V RBOB	0.0	0.0	0.0	0.0	4.9
U L S Diesel (15 ppm)	33.2	22.2	209.7	17.4	29.8
* Refined Product Import Prices (Step 3)					
Reformulated Mogas	37.98	36.70	36.74	36.44	37.78
Traditional Mogas	34.45	33.20	34.13	34.24	31.90
No. 2 Heating Oil	31.81	30.50	30.52	31.67	30.25
L S Diesel (500 ppm)	34.94	33.60	33.95	34.34	33.06
Low Sulfur Fuel Oil	23.16	22.27	22.39	19.05	22.01
High Sulfur Fuel Oil	20.20	19.25	19.60	18.06	18.22
Jet Fuel	33.41	31.96	31.21	31.58	31.63
Liquefied Pet. Gases	21.32	20.99	20.26	18.02	21.14
Petchem. Feedstocks	26.86	26.62	26.06	27.11	24.66
Other Refined Prod.	24.13	23.97	24.17	21.99	20.35
Methanol	32.95	31.87	32.62	33.37	30.56
M. T. B. E.	45.74	44.65	45.39	46.13	43.34
PADD V RBOB	0.20	0.33	0.32	0.17	35.31
U L S Diesel (15 ppm)	35.30	33.95	34.30	34.71	33.59
* Year: 2005					
* Refined Product Import Quantities (Step 1)					

Reformulated Mogas	100.8	5.1	25.1	5.1	5.1
Traditional Mogas	93.7	5.1	5.1	60.8	17.0
No. 2 Heating Oil	72.3	25.5	5.1	28.8	5.1
L S Diesel (500 ppm)	120.0	0.0	5.0	0.0	5.0
Low Sulfur Fuel Oil	105.2	5.1	5.1	5.1	75.4
High Sulfur Fuel Oil	40.3	6.8	131.2	5.1	55.1
Jet Fuel	75.4	53.6	55.1	63.9	5.1
Liquefied Pet. Gases	18.0	73.4	56.4	5.1	5.1
Petchem. Feedstocks	5.1	56.3	130.5	5.1	5.1
Other Refined Prod.	12.0	19.3	5.1	5.1	5.1
Methanol	5.1	5.1	5.1	5.1	5.1
M. T. B. E.	83.4	44.3	88.2	5.1	82.8
PADD V RBOB	0.0	0.0	0.0	0.0	5.1
U L S Diesel (15 ppm)	36.2	39.9	253.4	32.9	40.9
* Refined Product Import Prices (Step 1)					
Reformulated Mogas	29.35	29.59	29.54	29.32	30.31
Traditional Mogas	26.36	26.64	25.88	27.54	24.15
No. 2 Heating Oil	24.79	23.84	23.28	24.32	22.85
L S Diesel (500 ppm)	23.33	25.27	26.02	26.74	26.65
Low Sulfur Fuel Oil	17.08	15.92	15.81	13.66	15.61
High Sulfur Fuel Oil	14.73	14.29	13.54	10.70	13.40
Jet Fuel	26.08	24.14	24.30	24.55	24.63
Liquefied Pet. Gases	15.81	15.79	15.77	12.73	15.58
Petchem. Feedstocks	20.49	18.88	19.80	20.36	18.15
Other Refined Prod.	18.43	17.66	17.36	14.61	15.71
Methanol	25.45	25.43	25.11	25.88	23.24
M. T. B. E.	38.02	37.31	37.75	38.23	35.74
PADD V RBOB	1.46	1.60	1.32	1.80	28.62
U L S Diesel (15 ppm)	29.16	27.91	28.34	28.29	29.34
* Refined Product Import Quantities (Step 2)					
Reformulated Mogas	95.1	5.0	23.6	5.0	5.0
Traditional Mogas	88.4	5.0	5.0	57.3	16.0
No. 2 Heating Oil	68.2	24.1	5.0	27.1	5.0
L S Diesel (500 ppm)	120.0	0.0	5.0	0.0	5.0
Low Sulfur Fuel Oil	99.2	5.0	5.0	5.0	71.0
High Sulfur Fuel Oil	37.9	6.3	123.7	5.0	52.0
Jet Fuel	70.8	50.5	51.9	60.1	5.0
Liquefied Pet. Gases	17.6	69.2	53.1	5.0	5.0
Petchem. Feedstocks	5.0	53.0	123.0	5.0	5.0
Other Refined Prod.	11.7	18.2	5.0	5.0	5.0
Methanol	5.0	5.0	5.0	5.0	5.0
M. T. B. E.	78.7	41.8	83.3	5.0	78.0
PADD V RBOB	0.0	0.0	0.0	0.0	5.0
U L S Diesel (15 ppm)	34.1	37.6	238.9	31.0	38.5
* Refined Product Import Prices (Step 2)					
Reformulated Mogas	31.98	30.71	30.28	31.16	31.93
Traditional Mogas	29.31	27.16	27.74	28.21	25.87
No. 2 Heating Oil	26.44	25.24	24.75	25.93	24.72
L S Diesel (500 ppm)	25.59	28.41	28.16	28.35	27.36
Low Sulfur Fuel Oil	17.69	17.60	17.87	15.24	17.51
High Sulfur Fuel Oil	15.68	15.20	15.23	12.78	14.08
Jet Fuel	27.67	26.16	25.63	26.03	26.98

Liquefied Pet. Gases	17.47	16.51	15.97	13.69	16.46
Petchem. Feedstocks	21.45	21.14	21.19	21.53	19.03
Other Refined Prod.	19.00	19.46	19.52	16.07	16.21
Methanol	27.80	26.63	27.13	28.02	25.09
M. T. B. E.	39.70	39.05	38.80	39.76	37.16
PADD V RBOB	2.26	1.75	1.73	1.95	29.92
U L S Diesel (15 ppm)	30.57	30.58	30.12	30.90	29.41
* Refined Product Import Quantities (Step 3)					
Reformulated Mogas	130.0	4.9	22.9	4.9	20.0
Traditional Mogas	125.0	4.9	4.9	55.7	15.5
No. 2 Heating Oil	66.1	23.3	4.9	26.3	4.9
L S Diesel (500 ppm)	120.0	0.0	50.0	0.0	5.0
Low Sulfur Fuel Oil	96.2	4.9	4.9	4.9	68.9
High Sulfur Fuel Oil	36.9	6.2	119.9	4.9	75.0
Jet Fuel	68.7	49.0	50.4	58.4	4.9
Liquefied Pet. Gases	17.3	67.2	51.4	4.9	4.9
Petchem. Feedstocks	4.9	51.4	119.3	4.9	4.9
Other Refined Prod.	20.0	17.6	15.0	4.9	15.0
Methanol	4.9	4.9	4.9	4.9	4.9
M. T. B. E.	76.3	40.5	80.7	4.9	75.6
PADD V RBOB	0.0	0.0	0.0	0.0	20.0
U L S Diesel (15 ppm)	33.1	36.4	231.7	30.1	37.3
* Refined Product Import Prices (Step 3)					
Reformulated Mogas	34.46	33.02	33.54	33.66	34.00
Traditional Mogas	31.17	29.98	30.19	30.92	27.06
No. 2 Heating Oil	28.07	27.19	26.38	27.12	26.47
L S Diesel (500 ppm)	27.44	28.85	29.96	30.60	29.31
Low Sulfur Fuel Oil	19.15	18.63	18.94	15.29	18.38
High Sulfur Fuel Oil	17.43	15.94	15.82	13.90	15.63
Jet Fuel	28.69	27.24	27.87	27.37	28.27
Liquefied Pet. Gases	17.90	17.16	16.95	14.36	17.64
Petchem. Feedstocks	23.65	23.15	23.30	23.71	20.56
Other Refined Prod.	20.75	19.94	20.37	17.01	19.03
Methanol	29.65	27.75	28.44	29.41	26.62
M. T. B. E.	41.79	39.91	40.31	42.13	38.57
PADD V RBOB	2.43	2.05	2.01	2.13	32.15
U L S Diesel (15 ppm)	32.95	31.09	31.92	32.21	30.86
* Year: 2010					
* Refined Product Import Quantities (Step 1)					
Reformulated Mogas	108.4	5.1	27.0	5.1	22.6
Traditional Mogas	135.3	5.1	5.1	92.0	17.1
No. 2 Heating Oil	117.6	26.5	5.1	39.8	5.1
L S Diesel (500 ppm)	24.0	0.0	1.0	0.0	1.0
Low Sulfur Fuel Oil	131.7	5.1	8.8	5.1	99.8
High Sulfur Fuel Oil	28.2	5.1	123.2	5.1	46.1
Jet Fuel	81.1	102.3	59.2	79.6	22.1
Liquefied Pet. Gases	19.3	80.3	83.2	5.1	5.1
Petchem. Feedstocks	5.1	61.5	141.2	5.1	5.1
Other Refined Prod.	12.9	38.9	5.1	5.1	5.1
Methanol	5.1	5.1	5.1	5.1	5.1
M. T. B. E.	89.4	47.7	101.8	5.1	88.3
PADD V RBOB	0.0	0.0	0.0	0.0	22.6

U L S Diesel (15 ppm)	120.0	0.0	5.0	0.0	5.0
* Refined Product Import Prices (Step 1)					
Reformulated Mogas	32.17	31.74	30.85	30.53	31.17
Traditional Mogas	27.52	26.97	27.20	28.74	24.73
No. 2 Heating Oil	25.43	24.56	24.05	25.45	23.75
L S Diesel (500 ppm)	25.80	26.50	25.94	27.63	26.85
Low Sulfur Fuel Oil	17.89	16.29	16.40	13.67	16.27
High Sulfur Fuel Oil	14.50	13.81	13.88	11.56	13.21
Jet Fuel	25.54	25.59	24.21	24.53	25.72
Liquefied Pet. Gases	15.51	15.75	15.03	12.41	15.72
Petchem. Feedstocks	20.53	19.99	20.54	20.17	18.31
Other Refined Prod.	18.79	17.59	18.21	13.71	16.58
Methanol	26.65	25.81	26.62	27.13	24.33
M. T. B. E.	38.79	38.46	38.59	39.90	36.18
PADD V RBOB	1.96	1.70	2.10	1.65	29.23
U L S Diesel (15 ppm)	28.96	28.01	27.08	28.14	28.56
* Refined Product Import Quantities (Step 2)					
Reformulated Mogas	102.3	5.0	25.4	5.0	21.2
Traditional Mogas	127.7	5.0	5.0	86.6	16.0
No. 2 Heating Oil	110.9	25.0	5.0	37.5	5.0
L S Diesel (500 ppm)	24.0	0.0	1.0	0.0	1.0
Low Sulfur Fuel Oil	124.2	5.0	8.3	5.0	94.1
High Sulfur Fuel Oil	26.5	5.0	116.1	5.0	43.5
Jet Fuel	76.2	96.5	55.8	75.0	20.8
Liquefied Pet. Gases	18.9	75.7	78.4	5.0	5.0
Petchem. Feedstocks	5.0	58.0	133.1	5.0	5.0
Other Refined Prod.	12.6	36.6	5.0	5.0	5.0
Methanol	5.0	5.0	5.0	5.0	5.0
M. T. B. E.	84.2	45.0	96.0	5.0	83.2
PADD V RBOB	0.0	0.0	0.0	0.0	21.2
U L S Diesel (15 ppm)	120.0	0.0	5.0	0.0	5.0
* Refined Product Import Prices (Step 2)					
Reformulated Mogas	33.96	33.63	32.17	32.40	33.90
Traditional Mogas	30.61	28.49	29.39	29.77	26.94
No. 2 Heating Oil	27.58	26.29	25.84	26.68	25.23
L S Diesel (500 ppm)	28.09	28.87	28.89	29.41	28.89
Low Sulfur Fuel Oil	18.81	17.60	17.88	15.59	17.69
High Sulfur Fuel Oil	16.08	15.18	15.85	13.61	14.56
Jet Fuel	28.46	26.39	26.57	26.63	27.41
Liquefied Pet. Gases	18.19	16.23	17.00	13.27	17.67
Petchem. Feedstocks	21.77	21.19	22.01	22.53	19.54
Other Refined Prod.	19.56	19.33	19.79	16.54	16.66
Methanol	29.09	27.67	27.63	28.63	26.65
M. T. B. E.	40.84	39.94	40.17	41.49	37.92
PADD V RBOB	2.03	1.88	2.32	2.03	32.13
U L S Diesel (15 ppm)	30.98	30.29	30.05	31.20	30.27
* Refined Product Import Quantities (Step 3)					
Reformulated Mogas	150.0	4.9	24.6	4.9	50.0
Traditional Mogas	150.0	4.9	20.0	84.1	15.5
No. 2 Heating Oil	107.5	24.3	4.9	36.4	4.9
L S Diesel (500 ppm)	40.0	0.0	20.0	0.0	1.0
Low Sulfur Fuel Oil	120.5	4.9	8.1	4.9	91.3

High Sulfur Fuel Oil	25.8	4.9	112.7	4.9	60.0
Jet Fuel	73.9	93.6	54.2	72.8	20.2
Liquefied Pet. Gases	18.6	73.4	76.0	4.9	4.9
Petchem. Feedstocks	15.0	56.2	129.1	4.9	4.9
Other Refined Prod.	30.0	35.6	15.0	4.9	4.9
Methanol	4.9	4.9	4.9	4.9	4.9
M. T. B. E.	81.7	43.6	93.1	4.9	80.7
PADD V RBOB	0.0	0.0	0.0	0.0	50.0
U L S Diesel (15 ppm)	280.0	0.0	70.0	0.0	5.0
* Refined Product Import Prices (Step 3)					
Reformulated Mogas	35.92	35.50	34.75	33.91	35.86
Traditional Mogas	31.47	30.70	30.95	32.15	28.60
No. 2 Heating Oil	29.15	27.92	27.70	29.13	26.79
L S Diesel (500 ppm)	30.86	31.30	31.13	31.85	30.15
Low Sulfur Fuel Oil	20.47	19.21	19.54	16.04	19.20
High Sulfur Fuel Oil	17.68	16.53	16.48	14.54	15.08
Jet Fuel	29.56	27.99	28.07	28.03	29.05
Liquefied Pet. Gases	18.94	17.77	17.02	15.26	18.55
Petchem. Feedstocks	24.73	23.04	23.29	24.35	21.00
Other Refined Prod.	22.06	20.63	20.69	17.68	18.74
Methanol	31.27	29.18	29.82	30.73	28.44
M. T. B. E.	42.58	41.43	42.23	42.71	40.07
PADD V RBOB	2.41	2.14	2.59	2.32	33.65
U L S Diesel (15 ppm)	31.84	32.38	31.78	32.92	31.69

APPENDIX E

Sample Imported Petroleum by Source

Reference Case
(Million Barrels per Day)

Sources	2002	2005	2010	2015	2020	2025	Annual Growth 2002-2025 (percent)
Crude Oil							
Canada	1.45	1.52	1.78	2.12	2.32	2.44	2.3%
Mexico	1.50	1.49	1.65	1.84	1.94	2.02	1.3%
North Sea	0.76	0.51	0.48	0.44	0.38	0.35	-3.3%
OPEC	4.09	4.76	5.57	6.92	7.69	8.69	3.3%
Latin America	1.20	1.38	1.61	1.82	2.08	2.28	2.8%
North Africa	0.03	0.05	0.10	0.13	0.15	0.17	7.8%
West Africa	0.59	0.75	0.83	0.99	1.12	1.23	3.2%
Indonesia	0.05	0.07	0.09	0.09	0.06	0.05	0.0%
Persian Gulf	2.22	2.51	2.94	3.89	4.28	4.96	3.6%
Other Middle East	0.05	0.03	0.03	0.04	0.05	0.04	-1.0%
Other Latin America	0.56	0.58	0.64	0.69	0.59	0.54	-0.2%
Other Africa	0.51	0.72	0.87	1.17	1.28	1.42	4.6%
Other Asia	0.22	0.23	0.27	0.31	0.28	0.26	0.7%
Total Crude Oil	9.14	9.84	11.29	13.53	14.53	15.76	2.4%
Light Refined Products							
Canada	0.44	0.45	0.46	0.45	0.50	0.71	2.1%
Northern Europe	0.17	0.17	0.16	0.11	0.10	0.13	-1.2%
Southern Europe	0.08	0.08	0.08	0.06	0.07	0.09	0.5%
OPEC	0.17	0.31	0.39	0.43	0.59	0.87	7.4%
Latin America	0.10	0.17	0.21	0.24	0.33	0.46	6.9%
North Africa	0.03	0.05	0.06	0.06	0.08	0.10	5.4%
West Africa	0.01	0.02	0.02	0.02	0.03	0.03	4.9%
Indonesia	0.01	0.01	0.01	0.01	0.01	0.02	3.1%
Persian Gulf	0.02	0.06	0.09	0.10	0.14	0.26	11.8%
Caribbean Basin	0.32	0.28	0.25	0.31	0.39	0.54	2.3%
Asian Exporters	0.12	0.10	0.11	0.13	0.15	0.22	2.7%
Other	0.07	0.07	0.09	0.08	0.11	0.15	3.4%
Total Light Refined Prod	1.37	1.46	1.54	1.57	1.91	2.71	3.0%
Heavy Refined Products							
Canada	0.09	0.10	0.12	0.13	0.17	0.18	3.1%
Northern Europe	0.14	0.13	0.08	0.09	0.11	0.12	-0.7%
Southern Europe	0.02	0.02	0.02	0.02	0.04	0.04	3.1%
OPEC	0.35	0.53	0.59	0.64	0.98	1.08	5.0%
Latin America	0.09	0.18	0.23	0.24	0.34	0.36	6.2%
North Africa	0.19	0.17	0.13	0.14	0.21	0.22	0.6%
West Africa	0.02	0.02	0.01	0.02	0.04	0.05	4.1%
Indonesia	0.01	0.02	0.02	0.02	0.03	0.04	6.2%
Persian Gulf	0.04	0.14	0.20	0.22	0.36	0.41	10.6%
Caribbean Basin	0.23	0.23	0.33	0.34	0.44	0.46	3.1%
Asian Exporters	0.10	0.11	0.13	0.14	0.20	0.21	3.3%

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  Other                   0.09  0.09  0.09  0.10  0.12  0.14      1.9%
                          ====  ====  ====  ====  ====  ====
Total Heavy Refined Prod  1.02  1.21  1.36  1.46  2.06  2.23      3.5%

Total Petroleum          11.53 12.51 14.19 16.56 18.50 20.70      2.6%
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