AN OVERVIEW OF SELECTED NATIONAL-LEVEL ENERGY/ TRANSPORTATION MATHEMATICAL MODELS

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UMI
RESEARCH PRESS

Published by UMI Research Press,
an imprint of University Microfilms
International, Ann Arbor, Michigan 48106.
Printed and bound in the United States
of America.

UM-HSRI-80-47

Library of Congress Cataloging in Publication Data

Michigan. University. Highway Safety Research Institute. Policy Analysis Division.

An overview of selected national-level energy/transportation mathematical models.

(Transportation series)
Bibliography: p.
Includes index.
1. Energy policy—United States—Mathematical models. 2. Energy consumption—United States—Mathematical models. 3. Transportation—United States—Energy consumption—Mathematical models. 4. Automobiles—United States—Fuel consumption—Mathematical models. I. Richardson, Barbara C., 1947- . II. Title. III. Series: Transportation series (Ann Arbor, Mich.)

HD9502.U52M52 1981 333.79'0724 80-28819
ISBN 0-8357-1125-0

ACKNOWLEDGMENTS

The efforts of many people were involved in producing this report. Their assistance and cooperation are gratefully acknowledged.

The Motor Vehicle Manufacturers Association (MVMA) Subcommittee on Federal Simulation Models served as an advisory committee to this project. Committee membership during fiscal year 1980 included Jack H. Merritt, chairman, Thomas N. Roynane, Sol Drescher, and Neil E. South. Christian van Schayk served as MVMA secretary to the committee.

This document is one of the work products of a study of mathematical models relating to the motor vehicle transportation system. The general research design was developed by Kent B. Joscelyn and Barbara C. Richardson, the co-principal investigators of the project. Barbara C. Richardson developed the specific approach that resulted in this report.

A number of Highway Safety Research Institute staff were indispensable in the preparation of this report. Robert W. Staiger and Lawrence D. Segel provided research assistance leading to summaries of several models. Lawrence D. Segel and Jerry S. Vidis provided support in the computer programming aspects of the project. Anne L. VanDerworp coordinated the word processing and report production. Doris L. Dunger and Suzanne J. Roberts each typed portions of the report.

Several authors and sponsors of models provided valuable input into the study. Particularly helpful were Charles A. Allen, Mary Carlson, Carmen Difiglio, Donald Gantzer, Mary J. Hutzler, Terry Morlan, Sharon Wagner, and Julie Zalkind of the U.S. Department of Energy, Mary D. Schrot of Lawrence Livermore Laboratory, Paul J. Groncki of Brookhaven National Laboratory, David L. Greene of Oak Ridge National Laboratory, Adele Shapanka of the CONSAD Corporation, and James L. Sweeney of the Energy Modeling Forum at Stanford University. These model authors and sponsors reviewed draft summaries of particular models and provided information about the most recent revisions to their models.

Without the cooperation and support provided by these individuals, the study would not have been possible. The responsibility, however, for any errors in this report lies entirely with the authors.

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Co-principal Investigator

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CONTENTS

Introduction

Since the early 1970s energy considerations have been growing in importance in the United States economy. Many national-level mathematical models have been developed as an aid in studying the relationship between energy and the economy. These models are generally dynamic multi-sector models capable of simulating alternative energy policies and economic and technological scenarios. Because the transportation sector is a major consumer of energy, having consumed about 33% of the net energy and 53% of all the petroleum used in the United States in 1978, most of these energy models contain a transportation component. Modeling the transportation sector is also important because over 97% of its energy requirements are based on the volatile world petroleum market (U.S. Department of Energy 1980).

This report presents the results of a review by staff of the Policy Analysis Division of The University of Michigan's Highway Safety Research Institute (HSRI) of national-level energy models that contain transportation sectors. It identifies and briefly describes the transportation sectors in the context of each overall model. Key aspects of these transportation components are compared. Some transportation components focus on the automobile sector, while other models consider several modes. The information presented in this report was collected during the period November 1979 through July 1980. As any survey of this rapidly changing field is likely to be incomplete, corrections or additions are appreciated by the authors.

Four energy modeling systems are included in the report: the Midterm Energy Forecasting System (MEFS), the Strategic Environmental Assessment System (SEAS), the SRI-Gulf Energy Model and derivative models, and the Brookhaven National Laboratory (BNL) energy models. These modeling systems have been selected for inclusion in this report because of the influence they may have on federal policy dealing with transportation and energy consumption.

TECHNICAL METHOD

The criteria for including a model in this paper are (1) it is a major model of the U.S. energy system, and (2) it has the capability to be used in automotive transportation policy analyses. Appropriate models were identified by contacting builders, users, and sponsors of models and by searching the literature.

During the search for models, several inventories of energy models were identified. One is A Catalog of Energy Models (Kline and Swift 1978) published by the Energy Modeling Forum (EMF) as an occasional paper in June 1978; the second is entitled Applied Analysis Model Summaries, prepared by the Office of Analysis Oversight and Access of the Energy Information Administration, U.S. Department of Energy (1979). The former contains models used throughout the world, while the latter contains only models currently used by the Office of Applied Analysis, Energy Information Administration. The EMF attempted to compile a comprehensive catalog, but recognized that the list was incomplete and requested that the modeling community send descriptions of excluded models.

A third compendium of energy models was produced by Synergic Resources Corporation (Limaye, Steigelmann and Davis 1980). That report examined the potential usefulness of existing energy models in simulating various alternative policies of the Pennsylvania state government. In developing that study, a working paper on transportation energy demand models was prepared (Colville and Limaye 1980). The working paper contains abstracts of five transportation models sponsored by the Department of Energy, Energy Information Administration. Four of these models as well as revised versions of those models are discussed here in the summary of the Midterm Energy Forecasting System (MEFS) transportation components. The fifth model was the Short-term Gasoline Consumption Model and is not included in this report because of the short forecasting horizon and indications by the model sponsors that it probably would not be used.

The search for models also identified the work of the International Institute for Applied Systems Analysis (IIASA) in Laxenburg, Austria. IIASA is a nongovernmental, international research institution founded by scientific organizations from around the world. (The U.S. member organization is the National Academy of Sciences.) IIASA has published a series of reports entitled A Review of Energy Models with the fourth and most recent report being by Beaujean and Charpentier (1978). Models reviewed in the series are both national and international. Many are national models particular to countries other than the U.S.

Although many energy model inventories do exist, it was nevertheless decided to compile this inventory because none of the existing ones addressed only those models that met the criteria stated above. To perform this study, documentation on models judged relevant was collected and reviewed. Information from the model's documentation was then organized into a standardized format used in this report. Information on each major energy model is organized by the following categories: model name, overview, uses, input data, output data, modeling structure and techniques, relationship to other models, computer requirements, transportation component, and references. For the transportation component of each model the following items are listed: structure, input, output, key assumptions used in constructing the model, relationships among variables, and references. Note that information was not always available for all models, and that no analyses of the models were performed.

The emphasis and details of the summaries differ somewhat across models and model systems. Different treatments for the various models were required because of the nature of the models, the limitations of the published documentation, and the focus of this study. For example, MEFS has some of the same capabilities as the other national energy model systems, but the emphasis in the MEFS section and in the summary is on the details of the transportation components. The transportation components in the other model systems are more an integral part of the system and are unlike the MEFS's transportation components in that they generally cannot stand alone. Because of the structure of those other systems, relatively more detail is presented on those nontransportation components than on those of the MEFS system. Readers interested more in the details of the nontransportation components of any of these models should contact the model system authors or sponsors.

As the model summaries depend primarily on model documentation, readers should be aware that the documentation generally provides only snapshots of constantly evolving models. Revisions to models sometimes remain undocumented. In addition, many of the models presented in this report are modified for use in specific studies. This is particularly true of models used by the U.S. Department of Energy (DOE). DOE has and will likely continue to modify models' structures, parameters, and assumptions to produce projections for various studies. When known, the revisions and modifications of the models are indicated. Undocumented information on model revisions was obtained primarily through telephone conversations and correspondence with model authors, sponsors, and users. Interested readers should contact the model user or builder about the details of a specific application of a model.

ORGANIZATION OF THE REPORT

The four sections following the Introduction present detailed reports on each of four major energy modeling systems, with an emphasis on their transportation components. Models are identified by name and by the accession number used in An Inventory of Selected Mathematical Models Relating to the Motor Vehicle Transportation System and Associated Literature (Richardson et al. 1979), the first supplement to that report (Richardson, Segel, and Joscelyn 1980) or by the accession number that will be used in forthcoming supplements of that inventory. (That inventory is also compiled by staff of The University of Michigan Highway Safety Research Institute. It contains models on a variety of subjects in addition to energy.) The detailed model reports are summarized in a fifth section that contains brief comparisons of the key features of both the energy models and their transportation components. The Appendix contains an annotated bibliography of models relevant to the forecasting of motor vehicle fuel consumption. Models described in the body of the report are not presented again in the Appendix. The emphasis in the Annotated Bibliography is on models that either do not have the scope of a major energy model or else are motor vehicle transportation models that forecast fuel consumption. Models in the Annotated Bibliography are arranged alphabetically by model name; the references are followed by a short model summary emphasizing those aspects relevant to forecasting motor vehicle fuel consumption. In each annotation, an accession number is indicated; this number is again the accession number used by Richardson et al. (1979) or that will be used in supplements to that inventory.

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U.S. Department of Energy, Energy Information Administration. 1979. Applied Analysis Model Summaries. Washington, D.C. Report no. DOE/EIA-0183/6.

U.S. Department of Energy, Energy Information Administration. 1980. Annual Report to Congress 1979 Volume Three. Washington, D.C. Report no. DOE/EIA-0173(79)/3.

Midterm Energy Forecasting System (MEFS)
(S-78-419)

Overview of Model

MEFS is a national energy forecasting system used to forecast energy prices, supplies, demands, and conversion activities. MEFS, which incorporates a revised version of the Project Independence Evaluation System (PIES), is the U.S. Department of Energy's major midterm (6-19 years out) energy forecasting system. It uses many models in its operation and is a tool that can be used to examine the potential impacts of changes in federal policies by the specification of alternate scenarios. It is intended to answer questions pertaining to:

- U.S. energy requirements in the next six to nineteen years;
- the mix and prices of fuels needed to satisfy these requirements;
- the geographic regions these fuels will be extracted from (or exported to), and where and how they will be converted from raw materials to refined petroleum products or electricity;
- method of fuel distribution throughout the country; and
- the types and capacities of new energy-related facilities (e.g., mines, refineries, electric generating plants) required to satisfy energy demands.

Uses

The predominant use of MEFS by the U.S. Department of Energy's (DOE) Energy Information Administration (EIA) is in preparing annual reports to Congress. MEFS is also used to simulate alternative policy scenarios. Since EIA was not intended to be a policy-advocating organization, the alternative policies simulated are usually in response to specific requests by non-EIA organizations, both within and outside DOE. However, in order to increase its own knowledge of the impacts of policies proposed by other government agencies, EIA occasionally initiates simulations.

Input

Communication with DOE staff working with MEFS has indicated that there is no comprehensive list of inputs to MEFS. The following list of inputs is based on a number of sources and is presented in order to give the reader an idea of the types of data required for a simulation. Please note that the list should not be considered to be complete and that the interested reader should consult with DOE staff about any specific model inputs.

- price expectations of energy producing industries
- price and tax information pertaining to oil and natural gas
- oil and natural gas pipeline rates of flow
- railroad rates for transporting coal
- cost and construction information related to additional nuclear capacity
- nuclear fuel cycle characteristics
- environmental standards, load managements, plant additions and retirements, and systems compliance options relating to the electric power industry
- weatherization programs, building standards, appliance standards, and tax credit and retrofit service information related to the residential sector
- building standards and Federal Energy Management Program (FEMP) information related to the commercial sector
- industrial sector inputs related to the environment, pollution control equipment, and the Powerplant and Industrial Fuel Use Act
- transportation sector inputs related to efficiency of diesels, vehicle fuel efficiency standards, and market penetration of diesel-powered vehicles
- macroeconomic forecasts based on work performed by Data Resources, Inc. (DRI), e.g., GNP, inflation, income, labor force, and business capital stock increases; many of these forecasts are by region
- oil and natural gas reserves (proven and inferred)
- shale oil production
- lease sales for oil and gas exploration

- natural gas import bounds
- world oil price
- oil industry costs, e.g., drilling costs, costs of additional refinery capacity, refining costs
- mandated and proposed plant conversion activity
- coal supply information, e.g., productivity, life of a mine, reserves
- price markups for major energy products
- aggregate price elasticities for major energy products
- population by region
- value added in the manufacturing sector by region
- value added in seven two-digit SIC industries by region

Output

Equilibrium quantities of energy supplied and demanded are forecast. Also produced are customized reports detailing energy production, consumption, conversion, and both retail and marginal prices associated with fuel production and consumption. Results are broken down by fuel, region, process, and consuming sector and are given in both BTU and standard physical units.

Modeling Structure and Techniques

MEFS has three major components: demand models, supply models and a mechanism that equilibrates the two. The relationship between these components is shown in Figure 1.

The demand and supply components as described by the DOE (1980b) are as follows:

> The demand models are econometric and structural representations of the end-use sectors that estimate consumer demands for fuels and energy as functions of prices, the general level of economic activity, value added in manufacturing, demographic trends, the nature and extent of conservation programs, and other demand-related scenario conventions. Demands are calculated in MEFS for refined petroleum products, natural gas, coal, electricity, and other fuels for each of the ten DOE regions and for each of the major consuming sectors: residential, commercial, transportation, and industrial (including use of energy materials as raw materials).
>
> The MEFS supply system is a detailed representation of U.S. energy resources and includes importation, production, conversion, and transportation activities. . . . A set of

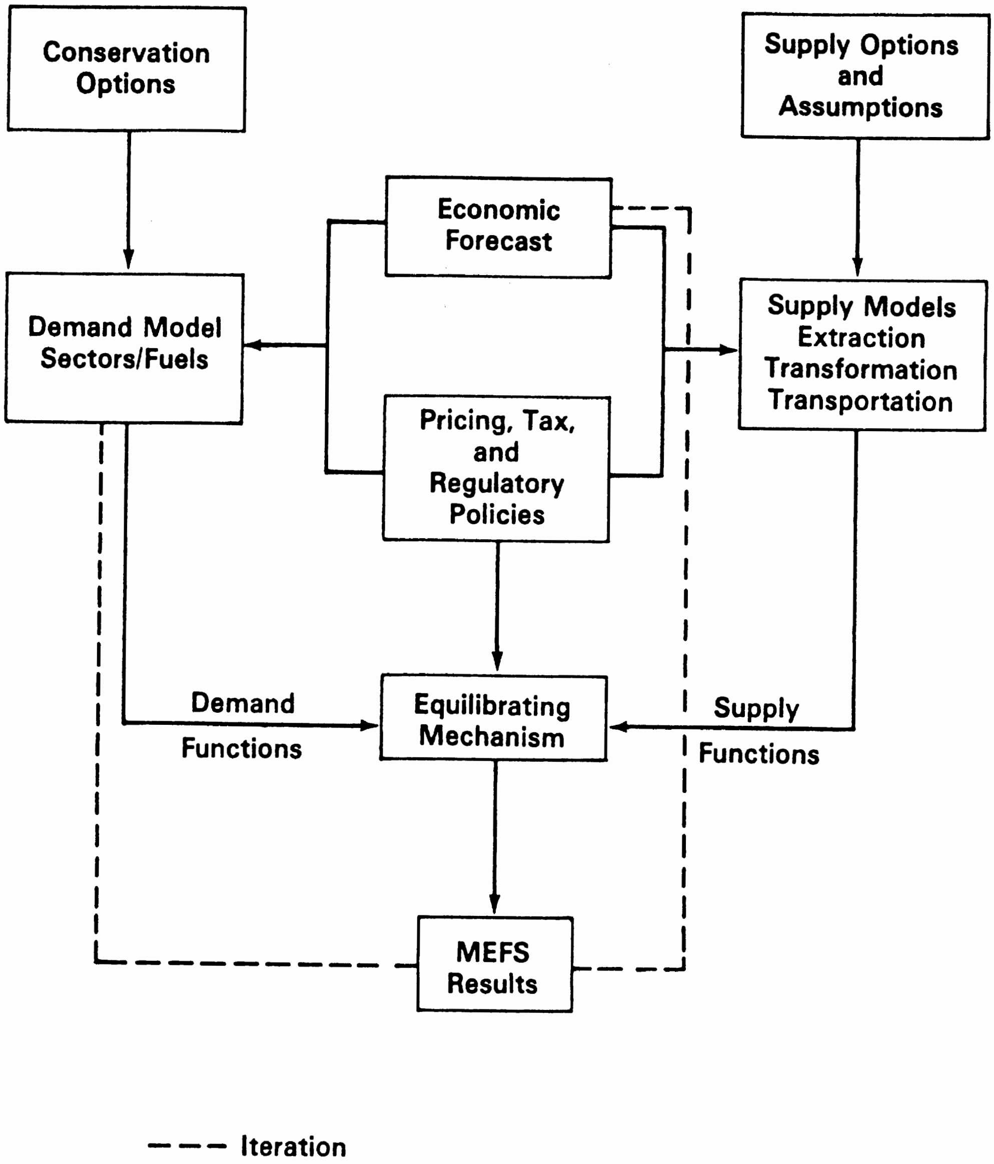

Figure 1
Schematic of the MEFS Integrating Framework

Source: U.S. Department of Energy 1980b

> satellite models is used to represent the supply for each of the major raw materials: coal, oil, natural gas, and uranium. (pp. 263-264)

A simplified flow of materials in MEFS is presented in Figure 2. The report (U.S. Department of Energy 1980b) also describes the model structure:

> The various sectors of MEFS are linked by a distribution network that represents the movement of raw materials or

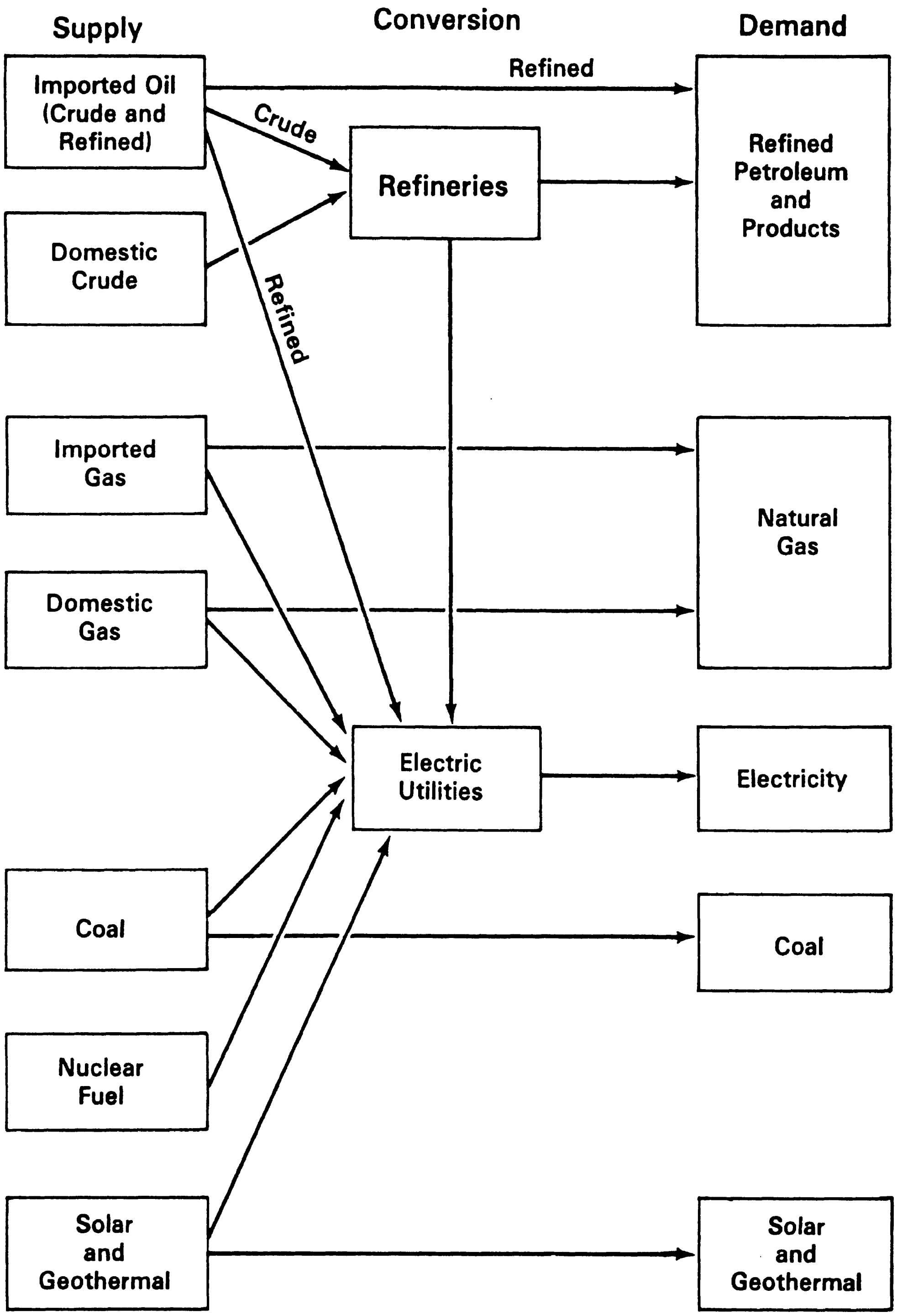

Figure 2
Simplified Flow of Materials in the MEFS Integrating Model

Source: U.S. Department of Energy 1980b

products from the points of production, import, or conversion to the locations at which they are converted or consumed.

The principal economic assumptions implicit in the MEFS model structure are the following:

- Market equilibrium conditions govern the purchase prices and quantities of fuel consumed subject to the constraints introduced by government regulations.
- Consumers substitute fuels on the basis of their relative prices.
- Suppliers are competitive and produce if the market price is at or above the minimum acceptable selling price.
- The prices paid by energy consumers are marginal fuel prices, except for electricity and natural gas, which are sold at average prices. (p. 265)

Relationship to Other Models

Since MEFS is comprised of many models, it is considered to be a modeling system. The MEFS satellite models are shown in Figure 3. A survey of these can be found in the U.S. Department of Energy report, Applied Analysis Model Summaries, (1979b). The major models or model systems of MEFS are the Mid-Term Energy Market Model (MEMM) (formerly PIES), the Mid-Term Oil and Gas Supply Model, the National Coal Model, the Regional Energy Demand Forecasting Model (RDFOR), and the National Aggregate Refinery Model (NARM). RDFOR has recently been incorporated into the Demand Analysis System (DAS), a model system within MEFS. Only the transportation models related to MEFS are discussed below. Readers interested in the details and uses of the other MEFS models should contact the Energy Information Administration of the U.S. Department of Energy.

Computer Requirements

Processor: IBM 370/168

Input/Output devices: disk, tape

Storage: 1850K core; 400 cylinders scratch and/or permanent disk space

Language: FORTRAN, OMNI, MPSIII with WHIZARD, TSHS tape utilities.

References

U.S. Department of Energy. 1979a. Annual report to Congress 1978. Volume I. Washington, D.C.: Energy Information Administration report no. DOE/EIA-0173/1.

U.S. Department of Energy. 1979b. Applied Analysis Model Summaries. Washington, D.C.: Energy Information Administration report no. DOE/EIA-0183/6.

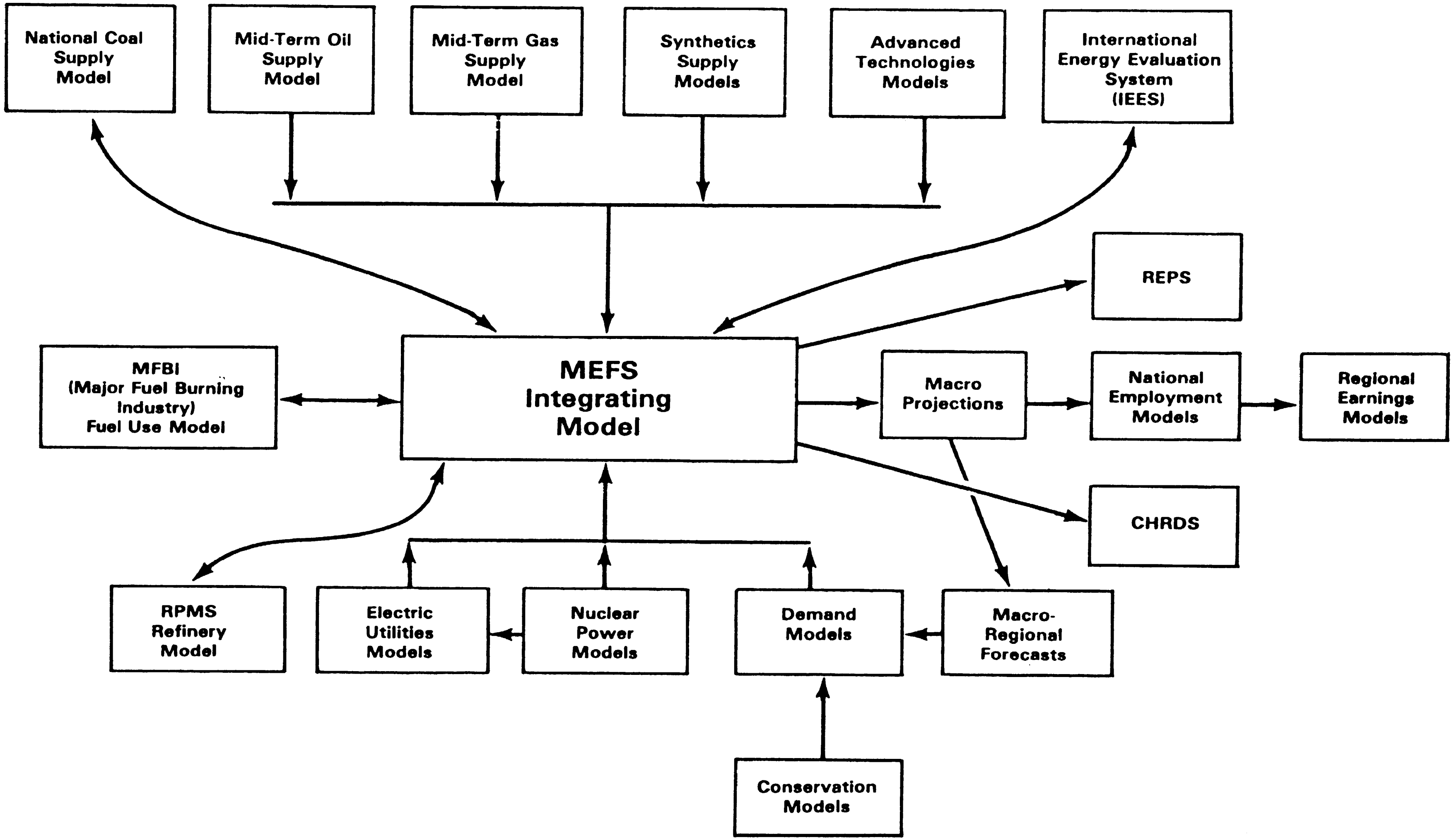

Figure 3
MEFS Satellite Models

Source: U.S. Department of Energy 1980b

U.S. Department of Energy. 1980a. Annual Report to Congress 1979 Volume I. Washington, D.C.: Energy Information Administration report no. DOE/EIA-0173(79)/1.

U.S. Department of Energy. 1980b. Annual Report to Congress 1979 Volume III. Washington, D.C.: Energy Information Administration report no. DOE/EIA-0173(79)/3.

Transportation Component

During 1978 and 1979, MEFS employed a number of models in the derivation of its energy forecasts for the transportation sector, including the use of inputs from models that are not internal to the system. The only transportation model that is internal to MEFS is embodied as the transportation sector submodel of the Regional Energy Demand Forecasting Model (RDFOR) in the Demand Analysis System (DAS).

DAS forecasts the quantities of fuel demanded by the residential, commercial, industrial, and transportation sectors of the economy. The residential sector submodel of DAS is currently the Hirst Model, developed at Oak Ridge National Laboratory. The commercial sector is represented by the Jackson Model, also of Oak Ridge National Laboratory. The industrial sector, largest of the energy consumption sectors, is only partially contained within DAS. The part within DAS was produced in-house at EIA. (The industrial sector is also represented by the Industrial Fuel Choice Allocation Model [IFCAM] and by a part of MEMM). The transportation sector in DAS is a multimodal model. The automobile sector is an EIA-modified version of the Sweeney Transportation Model authored by James Sweeney of Stanford University. The fuel requirements of the other modes are forecast with relatively small models that have been developed in-house at EIA.

The energy forecasts for the transportation sector are derived through a series of on-line model forecasts (internal to MEFS) and off-line model adjustments. The models that have been used or may be used in the future are:

- Sweeney Transportation Model;
- Passenger Car Gasoline Demand Model (a revised version of the Sweeney Transportation Model);
- EEA Light-Duty Vehicle Fleet Fuel Consumption Model (LDVFFCM);
- EEA Highway Fuel Consumption Model (a revised version of LDVFFCM);

- DOE/Faucett Automobile Sector Forecasting Model;
- ORNL State-Level Transportation Energy Demand Model (also referred to as the ORNL Highway Gasoline Demand Model); and
- Minor fuel models. These models are relatively small and forecast the fuel consumption of trucks, buses, trains, airplanes, ships, and pipeline. Historically, these models have been developed in-house at EIA, but Sweeney has developed a model that forecasts truck and off-highway gasoline sectors. This Sweeney model will likely be incorporated into MEFS for use in producing projections for the 1980 DOE/EIA Annual Report to Congress. Note that documentation on these models is not generally available and, therefore, these models are not described in this report.

For the 1978 Energy Information Administration (EIA) Annual Report to Congress (ARC 78), which relies heavily on MEFS, forecasts from the Sweeney Transportation Model were selectively modified using forecasts from the EEA Light-Duty Vehicle Fleet Fuel Consumption Model and the DOE/Faucett model. Given some Data Resources, Inc. (DRI) macroforecasts, the DAS transportation submodel forecast a baseline for automobile and light truck fuel consumption. The Faucett Model produced the "conservation shift" in fuel consumption caused by the automobile fuel economy regulations. The Light-Duty Vehicle Fleet Fuel Consumption Model produced the fuel conservation shift caused by light-duty truck fuel efficiency standards. The DAS forecasts were modified by the results of these off-line models and were then input into MEFS to be used along with the other mode forecasts to arrive at estimates of fuel prices and fuel consumptions determined by the entire MEFS system.

For its 1979 Annual Report to Congress (ARC 79), EIA used a slightly revised transportation sector model. The Sweeney Transportation Model remained as the automobile sector model, but with the automobile sales forecasts being those supplied exogenously by DRI. EIA did not use the DOE/Faucett model for the report. However, the EEA Light-Duty Vehicle Fleet Fuel Consumption Model (LDVFFCM) was again used for off-line adjustments. LDVFFCM was used to produce the fuel conservation shifts caused by the light-duty truck fuel efficiency standards and the impact of the market penetration of diesel engines in both automobiles and light-duty trucks. These shifts modified the DAS forecasts for gasoline and diesel consumption in the transportation sector.

For the 1980 Annual Report to Congress (ARC 80), EIA plans to replace the Sweeney Transportation Model (the DAS transportation submodel) with the Passenger Car Gasoline Consumption Model. EIA will have the option of modifying the DAS forecasts to reflect the projections from two new models. The State-Level Transportation Energy Demand Model (a stand-alone model developed at Oak Ridge National Laboratory [ORNL]) may be used for the regionalization of national forecasts, among other uses. The Light-Duty Vehicle Fleet Fuel Consumption Model has been expanded to include medium-and heavy-duty trucks. The expanded version is referred to as the EEA Highway Fuel Consumption Model and will also be available to EIA for use in developing projections for the 1980 Annual Report to Congress.

The major models involved in the midterm forecasting of the fuel consumption of the transportation sector are presented below. These are the Sweeney Transportation and Passenger Car Gasoline Consumption Models, the EEA Light-Duty Vehicle Fleet Fuel Consumption and Highway Fuel Consumption Models, the DOE/Faucett Automobile Sector Forecasting Model, and the ORNL State-Level Transportation Energy Demand Model. Each of these transportation sector models assumes a perfectly elastic supply of fuel at the given price. Fuel prices and available quantities are determined elsewhere in MEFS.

It should be noted that the reviews presented here are based primarily on available model documentation. EIA has modified and likely will continue to modify the structure, parameters, or assumptions of models in developing projections for various studies or reports. When known, the EIA modifications for particular reports are noted in the model descriptions here.

SWEENEY TRANSPORTATION MODEL AND PASSENGER CAR GASOLINE CONSUMPTION MODEL (79-254)

Overview of Model

The Passenger Car Gasoline Consumption Model is a modified version of the Sweeney Transportation Model, which is currently a part of the Transportation Sector Model in the Demand Analysis System (DAS) of MEFS. The Passenger Car Gasoline Consumption Model is a stock adjustment model that pays particular attention to the process of capital stock adjustment and stock utilization. The model is intended to analyze potential impacts of federal policies on the demand for gasoline in automobile use. As noted above, Sweeney also models the truck and off-highway gasoline sectors. These are not discussed here as there is no available documentation.

The Passenger Car Gasoline Consumption Model will soon replace the older Sweeney Transportation Model in DAS. As the two models are very similar, this report addresses only the Passenger Car Gasoline Consumption Model. Major differences in structure or methodology between the two models are identified.

Modeling Structure and Techniques

The Passenger Car Gasoline Consumption Model employs two fundamental determinants of automobile gasoline demand: the fuel efficiency of the existing stock of automobiles and the degree to which that stock is utilized. Fleet fuel efficiency is based on the efficiencies of automobiles by vintage, relative vehicle miles traveled (VMT) by vehicle vintage and the number of cars of each vintage. Utilization of the stock is measured as VMT and is much more responsive in the short run than the fuel efficiency of the stock.

To arrive at the average fuel efficiency for the fleet of automobiles in any given year, a number of simplifications are made. First, the fuel efficiency of a specific model is assumed to be proportional to the curb weight, with the constant of proportionality varying from year to year. Averaging over the existing models of a given vintage, mean fuel efficiencies of automobiles from any desired vintage, or "vintage efficiencies," may be calculated. The vintage efficiencies are assumed to remain constant throughout the life of the automobiles. Second, the "effective stock" is defined as the stock of new cars that would provide the equivalent level of service provided by the actual stock of automobiles. It is assumed that the level of automobile services declines geometrically with the age of the automobile. The effective stock measure for a given year is obtained by summing all new cars in that year and the rest of the existing fleet measured in new car equivalents. The average fuel efficiency of the stock of automobiles in a given year is then calculated as the geometric mean of vintage efficiencies, with weights corresponding to the effective stocks from each vintage. This term varies slowly as new cars are purchased and old cars are utilized to a lesser extent over time.

The total vehicle miles traveled in a given year is predicted as a function of such variables as total automobile registrations, population, disposable income, and fuel costs per mile. Gasoline consumption is simply the quotient of total vehicle miles traveled in a given year and the average fuel efficiency of the fleet in that year. The most significant difference between this and the previous version of the model lies in the treatment of scrappage rates. While the previous model assumes an exponential scrappage rate throughout the life of a vintage, the present version attempts to explain scrappage rates as a function of vehicle miles per car and age.

The structural detail of the model is intended to be sufficient to facilitate examination of those policies that act through traditional economic variables, as well as those policies that are directed specifically towards influencing characteristics of the existing stock of automobiles.

The model is econometric. Estimation was performed using ordinary least squares. The major equations were estimated in logarithmic form. Several of the key equations in the model are presented below. The documentation contains many alternative estimates of equation specifications; those presented were selected by the model author to be incorporated into the model.

GAS = VM/AMPG

where:

GAS = the aggregate gasoline consumption by passenger cars

VM = the total vehicle miles obtained by the fleet of automobiles

AMPG = the mean efficiency of the fleet

$$AMPG_t = ES_t/[\sum_{i=t-15}^{t} NPCR_i\ (SU_{it})\ \ GAMMA^{(t-i)}\ (1/MPG_i) + ESAMOC_t]$$

where:

$AMPG_t$ = the mean efficiency of the fleet in year t

ES_t = the effective stock of automobiles in year t

$NPCR_i$ = the number of new passenger car registrations of vintage i

SU_{it} = the surviving fraction of the stock of automobiles of vintage i during year t

$GAMMA^{(t-i)}$ = the intensity of usage of automobiles from vintage i in year t

MPG_i = fuel efficiency for automobiles of vintage i

$ESAMOC_t$ = the ratio of $ES_t/AMPG_t$ calculated only for cars older than 15 years of age

$$\log(NCMPG) = \underset{(32.0)}{3.344} + \underset{(7.9)}{0.721}\ [\log(PG[-1])] + \underset{(N/A)}{0.279}\ [\log(EFF)]$$

R^2 = 0.86   DW = 2.1   Sample Period = 1957-1974

where t-statistics are in parentheses, and

NCMPG = new-car fuel efficiency

PG(-1) = lagged real gasoline price

EFF = technical efficiency of automobiles, = 1 in 1974

Sweeney (1979) indicates that "for the automobile simulation model" the constant was adjusted to 3.4096 in the NCMPG equation. This was done "to better reflect on-the-road mpg than do the EPA tests." EIA has used different coefficients in the new-car fuel efficiency equation. For ARC 79, the constant equaled 3.344, and the elasticities of fuel price and technical efficiency were 0.63 and 0.37, respectively. For ARC 80, the constant will be 3.41 and the elasticities will be 0.721 and 0.279, respectively.

$$\log(VM/Pop) = \underset{(1.2)}{2.381} - \underset{(-5.1)}{0.295}\,[\log(NCGCPM)] + \underset{(1.7)}{0.299}\,[\log(YD/Pop)] - \underset{(-4.9)}{1.540}\,[\log(HPEA)] + \underset{(2.6)}{0.519}\,[\log(PCR/Pop)] - \underset{(-0.5)}{0.006}\,[\log(DUMAH)] - \underset{(-0.3)}{0.004}\,[\log(DUM74)]$$

R^2 = .997 D.W. = 1.9 Sample Period = 1957-1977

where t-statistics are in parentheses, and

VM/Pop = total vehicle miles obtained by the fleet of automobiles, expressed per capita

NCGCPM = gasoline costs per mile of driving

YD/Pop = disposable income per capita

HPEA = average weekly hours of production workers on private nonagricultural payrolls

PCR/Pop = total number of passenger car registrations per year expressed per capita

DUMAH = a dummy variable included to account for changes in the historical data series

DUM74 = a dummy variable for the year 1974 to account for gasoline shortages and *ad hoc* rationing plans in that year

$$\log(NPCR/POP) = \underset{(4.5)}{16.993} - \underset{(-3.8)}{3.002}\,[\log(ESLO/POP)] + \underset{(3.5)}{2.325}\,[\log(YD/POP)] - \underset{(-1.4)}{0.479}\,[\log(PG)] - \underset{(-1.4)}{0.786}\,[\log(PCAR)] - \underset{(-4.0)}{0.049}\,(RU)$$

$\bar{R}^2$ = 0.82 DW = 1.8 Sample Period = 1953-1977

where t-statistics are in parentheses, and

NPCR/POP = new passenger car registrations per capita

ESLO/POP = effective stock available in a given year from earlier vintages, per capita

YD/POP = real disposable income per capita

PG = real price of gasoline

PCAR = index of new-car prices (the ratio of the consumer price index for new cars to the overall CPI)

RU = unemployment rate

Input

Exogenous variables input for a Passenger Car Gasoline Demand Model run are: the consumer price index (CPI), population, disposable income in constant 1972 dollars, unemployment rate, average weekly hours, average hourly earnings, average speed, prices of leaded and unleaded gasoline and of diesel fuel, technical fuel economy, efficiency factors, mean fuel economy of imported autos, the import fraction of sales, and for both domestic and foreign cars the fraction using leaded or unleaded gasoline or diesel fuel. Two additional exogenous variables are the policy variables, gasoline tax and mean fuel economy standard (in EPA terms).

Output

The model develops annual national forecasts from 1978 to 1995 for the following:

- fuel demand for automobiles;
- fleet efficiency;
- vehicle miles traveled;
- new-car sales; and
- size of automobile fleet.

Forecasts are each disaggregated by fuel type: leaded, unleaded, and diesel fuel.

Note that the intended purpose of this model is to project gasoline and diesel fuel demand for automobile use. Although it produces projections for several other variables, it is not designed to deal with these variables in the detail that it deals with gasoline demand.

Assumptions

Except where indicated, both Sweeney models are based on the following assumptions:

- average fuel efficiency for each automobile vintage remains constant over time;
- the elasticity of vintage efficiency with respect to gasoline price plus the elasticity with respect to technological efficiency (EFF) are constrained to sum to one;

- consumers calculate a desired stock of automobiles and adjust the total stock of cars from its existing level to its desired level through automobile purchases;
- consumers consider, among other characteristics, the capital costs and projected fuel costs of the different automobile models when purchasing a new car;
- in estimating operating costs, consumers expect future gasoline prices to be equal to current prices;
- under the current federal incentive program the EPCA fuel efficiency standards for automobiles will be met or exceeded;
- pretax gasoline prices are not altered by federal policy options;
- fuel efficiency for a model vehicle is proportional to its curb weight, with the constant of proportionality changing from year to year;
- miles traveled by a vehicle is a geometrically decreasing function of automobile age;
- exponential scrappage rate is assumed for all years, with the survival rate equal to 0.93 (Sweeney Transportation Model only);
- exponential function sufficiently explains scrappage rate of vehicles older than 15 years of age, with the survival rate equal to 0.86. (Passenger Car Gasoline Consumption Model only); and
- the process of refining petroleum is such that the quantities of gasoline and diesel supplied are assumed to equal quantities demanded; and furthermore, the quantities demanded of other petroleum products can also be met.

Relationship Among Variables

The transportation demand models assume that the supply of gasoline is perfectly elastic at the given price. Other models within MEFS simulate the petroleum product markets. The interaction between the demand and supply sides of the automobile market with respect to fuel efficiency levels is modeled through (1) inclusion of a "technical efficiency" term, which measures the supply side changes that modify the relationship between automobile weight and fuel efficiency through the introduction of such devices as electronic ignitions, more efficient drive trains, and high compression engines, and (2) an automobile price effect term, which accounts for any weight reduction measures such as utilization of lighter materials and "downsizing."

One difference between the two versions of the Sweeney Model appears in the relationships chosen for the vehicle miles traveled equation. First, unlike their representation in the Sweeney Transportation Model, vehicle miles of travel are expressed as a function of the number of automobiles on the road, among other things, in the Passenger Car Gasoline Consumption Model.

Second, the older version of the model uses a comprehensive cost per mile measure as an explanatory variable of vehicle miles. This cost per mile measure includes gasoline cost per mile and a measure of time costs per mile. The time cost measure is a function of wage rate, average vehicle speed, and riders per car. For the revised version of the model, Sweeney estimated the vehicle miles equation with both a comprehensive cost measure, as defined above, and a simple gasoline cost per mile measure. He chose the vehicle miles equation that included only gasoline cost per mile.

A third difference is the inclusion of several years of post-1973 data in the revised model. The Sweeney Transportation Model was estimated with data from the pre-1975 period. The use of additional post-1973 years permits the model to reflect the more recent patterns of fuel consumption and pricing.

A fourth difference between the two versions of the Sweeney Model is in the new-car sales equation. The Sweeney Transportation Model's equation is in log-linear form with new-car registrations per capita as the dependent variable. Independent variables are effective stock per capita, vehicle miles traveled per capita, real disposable income per capita, and the unemployment rate. All independent variables appear in log form except the unemployment rate, which is in linear form. The revisions to that model involved two additional independent variables: the real price of gasoline and an index of new-car prices. Both are in log form. The revised equation is presented above in the Modeling Structure and Techniques section.

A fifth difference between the two versions involves the estimation of scrappage. The Sweeney Transportation Model assumed an exponential scrappage function for all vintage automobiles. In the Passenger Car Gasoline Demand Model, an exponential scrappage function is assumed only for autos, fifteen years and older. Scrappage rates for autos less than fifteen years old are a function of age and cumulative vehicle miles.

References

Three generations of the Sweeney model have been identified, only two of which are discussed in this report. The references pertaining to the original (1975 version) model are:

Federal Energy Administration. 1975. Passenger car use of gasoline: An analysis of policy options. Office of the Assistant Administrator for Policy and Analysis, Office of Energy Systems. Washington, D.C.

Sweeney, J.L. 1975. A vintage capital stock approach: The demand for gasoline. Draft.

These references pertain to the Sweeney Transportation Model:

Sweeney, J.L. 1976. Demand for gasoline: A vintage capital model. Draft. Stanford, California: Stanford University, Department of Engineering-Economic Systems.

Sweeney, J.L. 1977a. The impact of the President's proposed gasoline tax and gas-guzzler tax on gasoline consumption. Stanford, California: Stanford University, Department of Engineering-Economic Systems.

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Sweeney, J.L. 1979a. Energy policies and automobile use of gasoline. Stanford, California: Stanford University, Energy Modeling Forum occasional paper no. EMF OP 2.0.

Sweeney, J.L. 1979b. Effects of federal policies on gasoline consumption. Stanford, California: Stanford University, Energy Modeling Forum occasional paper no. EMF OP 2.1.

The references pertaining to the Passenger Car Gasoline Demand Model are:

Morlan, T.H.; Gantzer, D.J.; and Emerson, F. 1980. Forecasting auto fuel demand: Latest developments at the Energy Information Administration. Paper presented at Fifth International Automotive Propulsion Systems Symposium, Dearborn, Michigan.

Sweeney, J.L. 1979. Passenger Car Gasoline Demand Model. Unpublished paper.

EEA HIGHWAY FUEL CONSUMPTION MODEL (HFCM) (80-563)

Overview of Model

The Energy and Environmental Analysis, Inc. (EEA) Highway Fuel Consumption Model (HFCM) is designed to forecast the total fuel consumption (leaded gasoline, unleaded gasoline, and diesel fuel) of motor vehicles through 1995 as a function of selected past and projected characteristics of the vehicle fleet. It is intended to facilitate a better understanding of the trends in fuel consumption resulting from certain conservation policy options relating to the transportation sector.

In its original form, the model projected fuel demand only for light-duty vehicles. That version of the model is called the Light-Duty Vehicle Fleet Fuel Consumption Model (LDVFFCM) (Energy and Environmental Analysis, Inc. 1978, 1979a, b, c, 1980a). LDVFFCM was used in the 1978 DOE/EIA Annual Report to Congress to modify selected projections provided by the Sweeney Transportation Model. For its use in that report, many of the exogenous inputs were supplied by a Data Resources, Inc. (DRI) macromodel. Estimates of fuel-conservation shifts by automobiles were provided by the DOE/Faucett Automobile Sector Forecasting Model. National forecasts of annual fuel consumption by vehicle class and fuel type, derived from the EEA model with the aid of DRI and Faucett inputs (as well as others), were fed into MEFS, which combined them with predictions of fuel use from other models to arrive at mid-term multimodal transportation fuel use figures.

For the 1979 DOE/EIA Annual Report to Congress, projections from LDVFFCM were used to modify projections produced by the Sweeney Automobile Transportation Model. The LDVFFCM projected the fuel conservation shift in light-duty trucks (LDT) due to the LDT fuel economy standards. For the annual report, DOE/EIA incorporated the assumption that diesel market penetration would rise to 10% of the new-vehicle markets for both automobiles and light trucks in 1985. Other assumptions included are that light-duty truck fuel economy standards are met through 1985 and that diesels are 50% more efficient than gasoline-powered vehicles.

LDVFFCM has been recalibrated using more current data. It has also been expanded to include medium- and heavy-duty trucks. HFCM is the expanded version (Energy and Environmental Analysis, Inc. 1980b). Present EIA plans do not include incorporating HFCM into MEFS; it may, however, continue to be used for off-line adjustments to MEFS forecasts.

Modeling Structure and Technique

The Highway Fuel Consumption Model is an accounting model that projects fuel consumption in the transportation sector by calculating two parameters: annual vehicle miles of travel, and average on-the-road fleet fuel efficiency. It is a deterministic model in that output variations can be directly attributed to past and projected vehicle fleet characteristics. There are no behavioral equations that use macroeconomic variables in an effort to derive forecasts of future fuel demand.

The calculation methods used to determine fleet vehicle miles of travel, average fleet fuel efficiency, and fleet fuel consumption in a given year for light-duty vehicles appear below:

$$TVMT_j = \sum_i \sum_k SP_{kj} \times RG_{ij} \times VMT_{kj}$$

where:

$TVMT_j$ = total VMT per vehicle type j (one of five categories of light-duty vehicles)

RG_{ij} = registration in year i of vehicle type j

SP_{kj} = scrappage (percent of new vehicle registrations of age k and vehicle type j left on the road)

VMT_{kj} = vehicle miles traveled of vehicle type j and age k

$$TFC_t = \sum_i \sum_k \sum_j RG_{ij} \times VMT_{kj} \times PCT_{ijt}/MPG_{ijt} \times ADJ$$

where:

TFC_t = total fuel consumed of type t (leaded, unleaded, diesel)

PCT_{ijt} = percentage of registrations in year i of vehicle type j and with engines of fuel type t (leaded, unleaded, diesel)

MPG_{ijt} = miles per gallon (mpg) of registrations of vehicles in year i and vehicle type j and fuel type t

ADJ = an optional discount factor that adjusts the EPA MPG to an on-road MPG

$$AMPG_j = TVMT_j/[\sum_i \sum_k (RG_{ijt} \times VMT_{kj}/MPG_{ijt})]$$

where:

$AMPG_j$ = average fleet mpg for vehicle type j

RG_{ijt} = registrations in year i of vehicle type j with fuel type t

The equations used to calculate fleet vehicle miles of travel, average fleet fuel efficiency, and fuel consumption for medium- and heavy-duty trucks are identical to those used in the light-duty ve[illegible]e segment of the model except for two important differences:

- The medium- and heavy-duty truck fuel economy inputs are on-road values. No adjustment factor is needed to discount these estimates.
- The calculation of total VMT per vehicle type is based on estimates of annual VMT per truck by age and fuel type (diesel vs. gasoline). This reflects the fact that diesel-fueled heavy-duty trucks are used primarily in high-mileage over-the-road applications, whereas gasoline-fueled heavy-duty vehicles are generally limited to local and short-haul use.

Input

Input data are disaggregated into the following vehicle categories: domestic passenger automobiles, imported passenger automobiles, three categories of light-duty trucks by weight and origin, and three categories of medium- and heavy-duty trucks classified by weight. Inputs to the light-duty vehicle component of the model include:

- annual new-vehicle registrations by fuel type--leaded, unleaded, and diesel (Source: Technical Assessment Division of National Highway Traffic Safety Administration [NHTSA], and Wards Automotive Yearbook);
- scrappage rate of new vehicles (Source: NHTSA, DuPont);

- annual vehicle miles of travel per vintage vehicle year (Source: NHTSA);
- EPA test figures for vehicle average fuel economies (Source: U.S. Environmental Protection Agency [EPA]);
- on-the-road miles per gallon discount factor, which accounts for in-use driving conditions and reduces actual fuel economy below the EPA test values (Source: U.S. Department of Energy, and Energy Environmental Analysis, Inc.); and
- diesel penetration estimates.

All data for future years are estimates provided by DRI.

Inputs for the medium- and heavy-duty truck component of the model include:

- annual new vehicle registrations (Source: Motor Vehicle Manufacturer's Association [MVMA]);
- scrappage rate of new trucks (Source: Michigan Technological University, Kenworth Truck Co.);
- annual vehicle miles of travel per vintage vehicle year (Source: Michigan Technological University);
- new vehicle fuel economies (Source: EEA estimates derived from DOT and truck industry trade publications); and
- diesel penetration estimates (Source: MVMA, EEA estimates).

Data on new-truck registrations for future years are derived from DRI and are adjusted based on an analysis of current and projected trends in the mix of medium- and heavy-duty truck sales.

Output

Output for each year and for eight vehicle categories through 1995 includes:

- average new-vehicle fuel economy, both on-road and EPA (EPA for light-duty vehicles only);
- average fleet fuel economy, both on-road and EPA (EPA for light-duty vehicles only);
- new-vehicle registration for spark ignition and diesel engines;
- fleet vehicle registrations for spark ignition and diesel engines;
- total vehicle miles of travel disaggregated by vehicle type; and

- fuel consumption by diesel fuel, leaded gasoline, and unleaded gasoline.

Assumptions

The model is based on the following assumptions which are necessary to extend data where they are incomplete:

- The share of class I light trucks is assumed to increase from 25.8 percent of total new light-truck registrations in 1979 to 70 percent of the total in 1985 and remain constant thereafter. Imported light trucks are assumed to drop from 15.7 percent of the market in 1979 to 10 percent by 1985 and remain constant thereafter.
- The level of new-vehicle registrations in 1990 is assumed to remain constant through 1995.
- Domestic passenger cars are assumed to meet the Corporate Average Fuel Economy (CAFE) standards through 1985.
- Imported passenger car fuel economy is assumed to remain constant at 1980 levels through 1985.
- Light trucks are assumed to meet the CAFE standards through 1982. Fuel economies for 1983-1985 are based upon a U.S. Department of Energy--Energy and Environmental Analysis, Inc. analysis of recently proposed U.S. Department of Transportation mpg standards for 1985 model year light trucks.
- Post-1985 fuel economy for all categories of new vehicles are assumed to remain unchanged at 1985 levels.
- A twenty-five percent increase in fuel economy in diesel over the spark ignition engine is assumed for light-duty vehicles.
- Medium-duty trucks equipped with diesel engines are assumed to have a 59 percent advantage in fuel economy; light-heavy duty trucks with diesel engines are assumed to obtain a 69 percent increase in fuel economy relative to those with ignition engines.

Relationships Among Variables

There are no behavioral relationships among the variables in this model. By treating as exogenous all such relationships, the model implicitly incorporates into its forecasts the assumptions and behavioral relationships of the particular models from which it derives estimates of parameter values.

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Energy and Environmental Analysis, Inc. 1979b. Light duty vehicle fuel consumption model: Recent modifications in the input data and methodology and resulting changes in estimates of fuel demand. Arlington, Virginia.

Energy and Environmental Analysis, Inc. 1979c. Review of historical and projected future trends in annual VMT/passenger car and fuel demand and calibration of the light duty vehicle fleet fuel consumption model. Arlington, Virginia. Prepared for the U.S. Department of Energy, Office of Conservation and Advanced Energy Systems Policy.

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McNutt, B., and Dulla, R. 1979. On-road fuel economy trends and impacts. Washington, D.C.: U.S. Department of Energy and Arlington, Virginia: Energy and Environmental Analysis, Inc.

AUTOMOBILE SECTOR FORECASTING MODEL (76-016)

Overview of Model

The Automobile Sector Forecasting Model, commonly referred to as the Faucett Model, was written in 1976 by Jack Faucett Associates, Inc., under the sponsorship of the Federal Energy Administration. The Faucett Model is a long-term econometric stock-adjustment forecasting model. The model is relatively small and is designed to forecast the effects of such policies as fuel economy standards, gasoline taxes, excise taxes, and rebates on: gasoline consumption, vehicle miles traveled (VMT), new-car prices and sales, the number of cars in use (by size and age), and fuel economy. These forecasts are generated by the model given a proposed policy, in the context of projected technological cost relationships, demographic trends, and economic conditions.

Modeling Structure and Techniques

The Faucett Model is made up of two major components: an automobile industry simulation component and an automobile demand and travel forecasting component.

The automobile industry simulation component determines fuel economies and prices of three size classes of cars: small, medium, and large. These fuel economies and prices are calculated through a complex procedure that attempts to minimize the sum of: (1) the cost of a car to the consumer; (2) the cost of automobile travel to the consumer (this is inversely related to fuel economy); (3) the taxes to the consumer that may result under a tax/rebate program based on the fuel economy of cars; and (4) the civil penalties to the industry that can occur as a result of the fuel economy standards.

The demand and travel forecasting component determines the result of the price and fuel economy decisions on new-car sales, travel demand, and gasoline consumption. This component of the model is based essentially on a stock-adjustment approach, and it is composed of several interrelated equations including those for surviving cars on the road, generalized price, target auto ownership, new-car sales, market shares, vehicle miles traveled, and gasoline consumption. The major equations in the model are as follows:

$$\log(N_t) = \underset{(1.4240)}{5.45746} + \underset{(0.21001)}{0.21779}\,[\log(O^*_t - Autos_t - D_t)] - \underset{(0.44124)}{1.7039}\,[\log(X^*_t)]$$

where standard errors are in parentheses, and

N_t = total new-car sales in year t

O^*_t = target ownership of automobiles in year t

$Autos_t$ = the stock of automobiles on hand as of January 1 of year t

D_t = the number of autos scrapped during year t

X^*_t = an index of the real generalized price of new cars, 1967 = 1.00

$$O^*_t = (\sum_I H_I\, P_{It})\, HHLD_t$$

where:

H_I = the number of cars per household for income group I

P_{It} = fraction of total households in year t having income I

$HHLD_t$ = the total number of households existing in year t

$$\log(H_I) = -1.7481 + 0.4743\,[\log(I)]$$

where:

I = midpoint of income bracket for income group I

$$\ln\left(\frac{S^C_t}{1-S^C_t}\right) = \underset{(1.3983)}{-4.1749} - \underset{(1.0526)}{1.8660}\,(B_1)\,Y^S_t - \underset{(3.4071)}{2.0765}\,(B_2)\,Y^M_t - \underset{(1.6215)}{0.4299}\,(B_3)\,Y^L_t + \underset{(1.4913)}{3.5450}\,(B_2)\,Y^S_t + \underset{(1.6586)}{3.5093}\,(B_1)\,Y^M_t + \underset{(2.0077)}{1.8117}\,(B_3)\,Y^M_t + \underset{(2.3472)}{0.2589}\,(B_2)\,Y^L_t + \underset{(1.0249)}{5.6428}\,S^C_{t-1}$$

where standard errors are in parentheses, and

S^C_t = new-car market share of size class C (small, medium, and large cars) in year t

B_1, B_2, B_3 = dummy variables with a value of one for small, medium, and large car observations, respectively; zero otherwise

$Y^S{}_t$, $Y^M{}_t$, $Y^L{}_t$ = an index of the real generalized price of small, medium, and large cars, respectively, relative to that of all new cars in year t, 1967 = 1.00

$$SPG_t = \underset{(0.04127)}{0.40675} - \underset{(0.04104)}{0.078433}\,(P_n)_t - \underset{(0.005085)}{0.015519}\,(U_t)$$

where standard errors are in parentheses, and

SPG_t = the rate of scrappage in year t of vehicles eight or more years of age

$(P_n)_t$ = an index of the real price of new cars in year t, 1967 = 1.00

U_t = the unemployment rate in year t

$$\frac{VMT}{HHLD_t} = \underset{(14492.1)}{-52979.8} + \underset{(4281)}{15087}\left[\log\left(\frac{DI_t}{HHLD_t}\right)\right]$$
$$+ \underset{(2307.1)}{6337.7}\,(Autos/HHLD_t) - \underset{(958.59)}{2204.24}\,[\log(100 \times CPM_t)]$$

where standard errors are in parentheses, and

VMT_t = total vehicle miles traveled in year t

DI_t = total real disposable income in year t

CPM_t = an index of the fleet real gasoline costs per mile in year t, 1967 = 1.00

$AMT_M = 17.9729 - 9.57841\,[\log(M)]$

AMT_M = annual miles traveled per automobile at age M

M = vehicle age in years

Data used to build the model were based in part on these sources:

- Survey of Consumer Finances, Survey Research Center, The University of Michigan;
- Nationwide Personal Transportation Study, Federal Highway Administration;

- Current Population Reports, U.S. Bureau of the Census;
- Highway Statistics, Federal Highway Administration;
- Census of Population, U.S. Bureau of the Census; and
- National Survey of October New Car Buyers, Rogers National Research.

Input

Data for these variables must be provided by the user: gasoline prices and new-car fuel economy policies (excise tax/rebate description, and fuel economy standards/penalties). Standard inputs supplied by the model authors are: population, income, unemployment rate, technology forecasts, and starting-year fleet composition and fuel economies.

Output

For each year, 1976-2000, the model outputs the following:

- new-car sales;
- new-car sales by size class;
- average fuel economy of new car fleet;
- fuel economy by class;
- new-car prices;
- new-car prices by class;
- number of cars in operation;
- cars in operation by size class;
- cars scrapped during year;
- vehicle miles traveled;
- total gasoline consumed; and
- size-class share weighted average generalized price (generalized price is purchase price plus operating cost).

Assumptions

The automobile industry simulation component represents the supply side of the automobile market. Car prices and fuel economy rating are forecast based on policy choices and projections of technological costs using a cost-minimizing algorithm. This algorithm simplifies the industry's behavioral characteristics by assuming the following:

- a horizontal supply curve;

- manufacturers minimize total cost to the consumer (including fuel costs and policy-imposed costs such as penalties and excise taxes);
- consumers bear the entire burden of policy-imposed costs; and
- the proportion of each size class produced by each of the manufacturers is constant over time.

On the demand side of the model, new-car sales are assumed to be related to the gap between a "target" (or desired) stock of automobiles and the existing stock. It is assumed that target automobile ownership is positively related to household income and that the rate at which automobile ownership per household increases with rising income per household declines at higher income levels. The model authors assumed that the desired and existing stocks of vehicles were in equilibrium in 1970 and estimated target ownership cross-sectionally from 1970 data. The model does not explicitly take into account commercial fleet demand.

Comments

The fuel economy technology cost relations incorporated into the supply-side algorithm of the Faucett model have been revised by Energy and Environmental Analysis, Inc. (1979). Those revisions have not and probably will not be incorporated into the Faucett model because it would require additional modifications and revisions of that model. Instead, those updated technological cost relations will likely be used in the supply side of the new disaggregate vehicle-demand model being sponsored by the U.S. Department of Energy.

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ORNL HIGHWAY GASOLINE DEMAND MODEL (HGDM) (78-263)

Overview of Model

The Oak Ridge National Laboratory Highway Gasoline Demand Model is a midterm (5-15 years forecast horizon) model developed for DOE/EIA Office of Applied Analysis to be used in conjunction with the Midterm Energy Forecasting System (MEFS). The model is a forecasting tool designed for use in evaluating policies and trends affecting regional economics, demographics, spatial structure, fuel price levels, and technological changes in light-duty highway vehicles. The forecast variables are new-vehicle sales, fleet composition, fuel efficiency (mpg), vehicle miles traveled (VMT), and fuel demand. These variables are forecast at the state, DOE regional, and national levels.

The Oak Ridge National Laboratory (ORNL) Highway Gasoline Demand Model (HGDM) is referred to by several names. These include the ORNL State-Level Transportation Energy Demand Model and the ORNL State-Level Gasoline Demand Model. The model has the capability to incorporate the market penetration of various motor vehicle technologies, not just for gasoline engines. It will also generally forecast fuel consumption by engine type or technology. The fuel types currently included are leaded and unleaded gasoline and diesel. The documentation (Greene, Rose, and Thomas 1980) indicates that the other vehicle types are Sterling and Brayton (turbine) engines, and electrics. These engine types are likely to change as future technologies and market influences become more apparent. Presently, the market penetration of electric vehicles can be simulated by the model but the fuel consumption of those vehicles is not forecast.

The model only forecasts the fuel consumption of light-duty vehicles. The fuel consumption of heavy-duty trucks is not included in the model. (The model authors do alert the potential user to possible problems caused by the assumption concerning heavy trucks.)

Modeling Structure and Technique

The model is based on household production theory, which represents the consumer as constrained by technology and a budget, and seeks to separate the effects on consumer behavior of household production technology from those of preferences. Thus, the model explicitly considers the impacts of transportation technology on energy use, as well as more traditional economic factors such as price and income. The long-run focus of the model is on changes in the stock of vehicles that alter fuel economy, and thus gasoline demand. In the short run, the aggregate stock of vehicles is fixed, but the model attempts to allow for consumer substitution among inputs in producing travel.

The model can be decomposed into five major submodels. The relationships of the submodels is diagramatically presented in Figure 4. These major submodels are: (1) the Motor Vehicle Demand Model; (2) the Fleetmix Model; (3) the Vehicle Efficiency Model; (4) the Gasoline Demand Model; and (5) the Fuels and Technology Assumptions Model. These submodels are discussed in more detail in the sections following the discussion of inputs and outputs.

Input

Because the model forecasts at the state level, a forecast run from 1977 to 2000 requires approximately 14,000 individual data. To facilitate the use of the large data base, the model authors have incorporated data handling aspects into the model's program. The model authors divided the data base into two types, "scenario defining" and "other".

The scenario defining exogenous data are those likely to be modified by the model user. The variables of this type are generally the economic and demographic data as well as the technical data related to fuel efficiencies. These variables are listed in Table 1. An interactive program facilitates the manipulation of these data for policy analysis. Model users can create a working data base from their own data or by modifying an existing data base. Users can select data from four different data bases provided by the model authors. The user's guide (Greene, Rose, and Thomas 1980) includes detailed instructions on how the various options can be implemented.

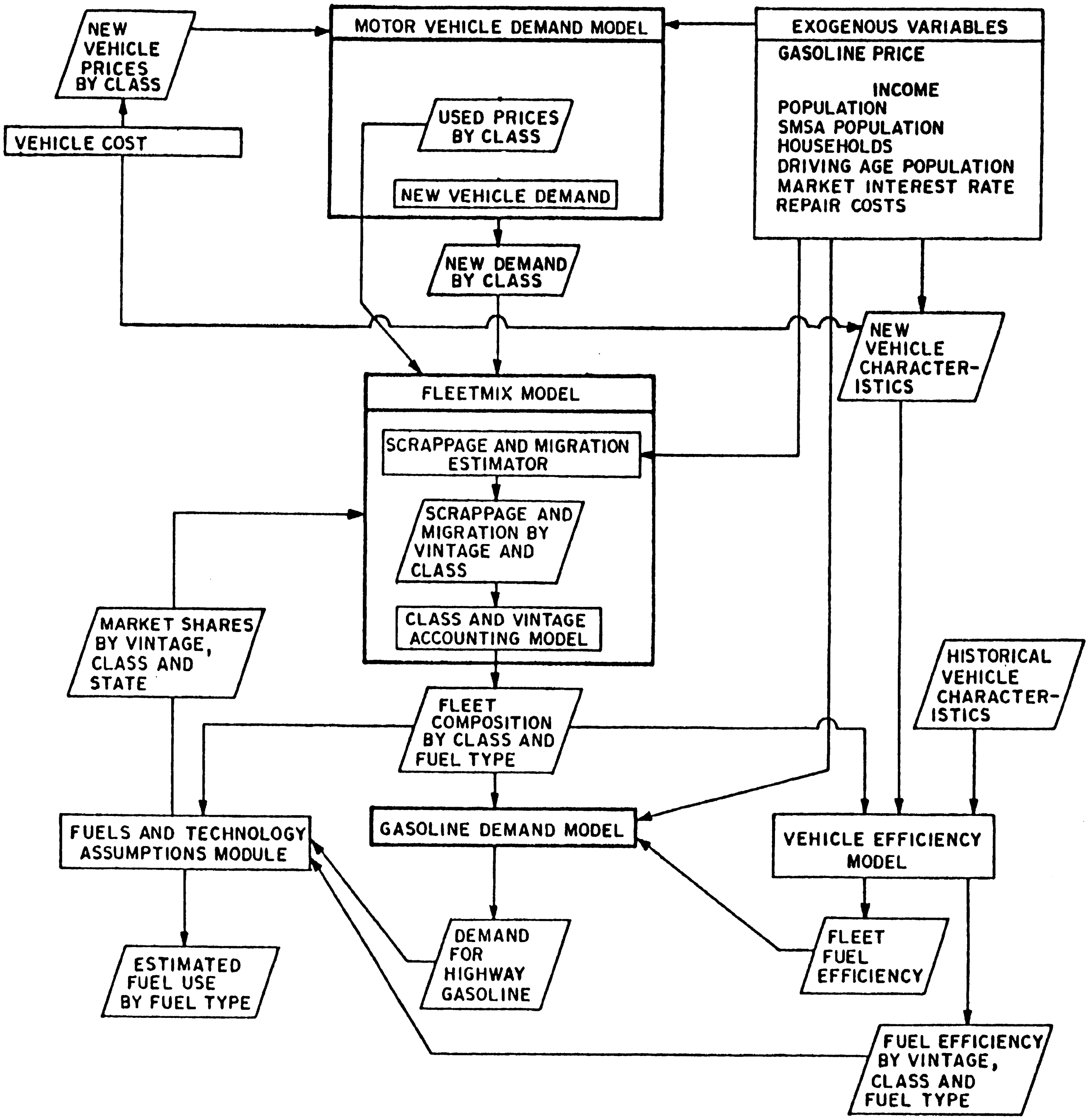

Figure 4
Highway Gasoline Demand Model Structure

Source: Greene and Rose 1980

The "other" exogenous data base contains those data that are not likely to be changed by the model user. These are generally the model's

TABLE 1
SCENARIO DEFINING EXOGENOUS DATA BASE*

	EPA Correction Coefficients
	Price Differential of Unleaded to Leaded Gasoline
	VMT vs. Age Correction Factors
S	Gasoline Price
V	New-Vehicle Price
S	Disposable Income
S	Unemployment Rate
S	Total Population
S	Number of Households
S	Population Under 18
S	SMSA Population
S	Population 18-44
S	Cost of Living Index
V	Fraction of Cars Using Unleaded Gasoline
V	City Fuel Economies for Diesel and Internal Combustion Engines
V	Highway Fuel Economies for Diesel and Internal Combustion Engines
T	% Fuel Efficiencies for Engine Types (Stirling, Brayton, other, or electric)
V	Fraction of Cars in Each Class Belonging to a Particular Engine Type (Internal Combustion, Diesel, Stirling, Brayton, other)
V	Unleaded Gasoline Fraction by Class
S	Rural VMT Fractions
S	State Trip-Length Fuel-Efficiency Correction Factors
S	State Temperature Fuel-Efficiency Correction Factors with Air Conditioning
S	State Temperature Fuel-Efficiency Correction Factors without Air Conditioning
S	1977 Gasoline Consumption
SV	1977 New Car-Sales by Class and State
S	Area of the States

* Note:
S indicates data by State
V indicates data by Vehicle Class
T indicates data by Engine Type

Source: Greene, Rose and Thomas 1980

coefficients and constants as well as the historical data required for the initial forecast year. These variables are shown in Table 2. The values in this data base can be modified, but the process involves using a text editor that is not part of the model's program.

Output

Output is produced for 1977 to 1995. Printed output can include the exogenous input data (to facilitate identifications and comparison of model runs), various intermediate calculations, and forecast variables. The forecast variables are presented at the state, federal region, and national levels of aggregation (all are by class and engine type). Those variables are:

- unit new-vehicle sales;
- fleet composition;
- miles per gallon;
- vehicle miles traveled; and
- fuel consumption.

HGDM SUBMODEL NAME: MOTOR VEHICLE DEMAND MODEL

The usual stock adjustment approach assumes that new and used vehicles are aggregatable commodities. HGDM is based on an alternative hypothesis that new vehicles are not simply additions to the stock, but are considered to be distinct, superior goods that are close substitutes for used cars. Furthermore, the authors conclude that different types of vehicles are also distinct commodities whose demand should be estimated separately. Thus, rather than having a new-vehicle shares equation and a set of market share equations, the model authors developed a set of demand equations, one for each vehicle class.

Six vehicle classes are defined by the model authors. Five are automobile classes whose characteristics are defined through a cluster analysis technique developed by McRae (1971). The sixth vehicle class is light-duty trucks (under 10,000 lbs). The cluster analysis of automobiles is based on the class distinctions of eight variables: (1) wheelbase, (2) curbweight, (3) engine displacement, (4) a roominess index, (5) number of passengers, (6) manufacturer's list price, (7) price divided by number of passengers, and (8) ratio of horsepower to curbweight. The average characteristics of each class are indicated in Table 3. The six vehicle classes may be briefly described as:

TABLE 2
OTHER EXOGENOUS DATA BASE

Name of Engine Types
State Names and FIPS Code Order
Name of Variable Commands Used to Modify Exogenous Data Base
Auto Finance Rate in Decimal Fraction
Maintenance Cost Index
State Relative Budget Shares for 6 Vehicle Classes
State Historical Average Differences in Vehicles in Operation for 6 Vehicle Classes (number of cars in one-year old equivalents)
By-Class New Vehicle Demand Equations: Coefficients and National Intercept Terms
State-Level New Vehicle Demand
Equation Intercept Terms for 6 Vehicle Classes
Gasoline Demand Equation National Intercept Term and Coefficients
State-Level Gasoline Demand Equation Intercept Terms
State-Level Scrappage and Migration Equation
State-Level 1977 Fleet 1 Composition by Vintage for 6 Vehicle Classes

Source: Greene, Rose and Thomas 1980

- Class 1: high performance, luxury sports cars;
- Class 2: large luxury cars;
- Class 3: small economy cars;
- Class 4: medium-sized economy cars;
- Class 5: large economy cars; and
- Class 6: light trucks under 10,000 pounds GVW.

Using a variance components estimation technique, equations were estimated for each of the six vehicle classes. The demands for the various classes are estimated as a function of the following variables: own price, other vehicle prices, fuel cost, fuel efficiency, income, household size, age (18-44), percent SMSA, population, and unemployment. The equations for the six classes are presented in Table 4. Implicit in the structure of this model is that new-vehicle supply is assumed to be perfectly elastic at the exogenously set price.

The Motor Vehicle Demand Model also contains equations that estimate used-vehicle prices by class as a function new-vehicle prices. Used-vehicle prices are used in the Fleetmix Model to project changes in the fleet composition.

HGDM SUBMODEL NAME: FLEETMIX MODEL

The Fleetmix Model represents the used-car market through the use of the Scrappage and Migration Estimator, and Class and Vintage Accounting Model. The former forecasts scrappage and migration rates by state, vehicle class, and vintage. The latter uses the forecasts to track the fleet composition over time.

The rate of vehicle scrappage is forecast by means of a probabilistic model that has scrappage rates as a function of vehicle age and used-car price. Individual equations were estimated for each state. Separate scrappage equations are included for the primarily domestic vehicle classes 2, 4, 5, and 6. Classes 1 and 3 are generally imported vehicles, and equations could not be estimated because of the data limitations. The specification of the Scrappage and Migration Estimator considers the interstate migration of certain vintages (1-4 years old) as well as state differences in vehicle lifetimes. Because of their specifications, the equations were estimated by means of a nonlinear least squares technique.

TABLE 3
AVERAGE CHARACTERISTICS OF VEHICLE CLASSES

Group	Wheelbase cm (in)	Roominess m^3 (ft^3)	Curb weight kg (lbs)	Engine displacement (in^3)	Price 1975 $	Number passengers	Price per passenger	Power to weight hp/kg (Hp/lb)
1	245 (96)	1.8 (63)	1261 (2780)	3.3 (202)	8066	2.6	3115	0.10 (0.046)
2	312 (123)	3.5 (123)	2168 (4781)	7.3 (442)	7815	5.8	1346	0.11 (0.050)
3	243 (95)	2.5 (90)	1049 (2312)	1.9 (118)	3648	4.3	889	0.08 (0.034)
4	286 (112)	3.1 (111)	1590 (3505)	4.9 (300)	4420	5.5	816	0.09 (0.041)
5	307 (121)	4.2 (147)	1995 (4399)	6.0 (366)	5232	6.6	794	0.09 (0.039)
6	All light trucks under 4535 kg (10,000 lbs) Gross Vehicle Weight							

Source: Greene and Rose 1980

TABLE 4
VARIANCE COMPONENTS ESTIMATES OF NEW-CAR CLASS DEMAND EQUATIONS
USING TRANSFORMED DEPENDENT VARIABLE TECHNIQUE

Vehicle class	Intercept	Own price	Cross price	Gasoline	Income	Household size	Age 18–44	Percent SMSA	Population density	Unemployment	Residual variance (df)
Class 1	–5.523	–0.7	0.182	0.346	1.431	–1.450	-	0.237	0.050	–0.105	0.135
	(3.554)	*	(0.381)	(0.195)	(0.195)	(0.456)		(0.071)	(0.029)	(0.045)	(542)
Class 2	3.754	–2.5	1.449	–0.092	0.809	-	–1.878	0.090	-	–0.089	0.072
	(2.375)	*	(0.261)	(0.167)	(0.135)		(0.198)	(0.046)		(0.033)	(543)
Class 3	5.587	–0.9	0.463	0.271	0.338	–0.927	1.957	0.137	-	–0.191	0.085
	(2.057)	*	(0.188)	(0.148)	(0.153)	(0.435)	(0.243)	(0.053)		(0.034)	(537)
	Year 67	Year 68	Year 69	Year 70	Year 71						
	–1.334	–1.113	–0.881	–0.461	–0.201						
	(0.078)	(0.077)	(0.073)	(0.065)	(0.062)						
Class 4	2.770	–0.4	0.366	–0.072	0.062	0.892	-	-	0.056	–0.157	0.061
	(2.017)	*	(0.202)	(0.140)	(0.111)	(0.264)			(0.013)	(0.026)	(542)
	Year 77										
	0.317										
	(0.192)										
Class 5	0.004	–2.5	2.160	–0.126	0.440	2.169	–1.864	-	-	–0.236	0.059
	(2.498)	*	(0.254)	(0.162)	(0.142)	(0.380)	(0.236)			(0.034)	(542)
	Year 77										
	–0.483										
	(0.155)										
Class 6	1.193	–1.1	1.057	0.002	0.345	–1.349	0.626	–0.130	–0.265	–0.243	0.051
	(2.249)	*	(0.247)	(0.190)	(0.137)	(0.353)	(0.224)	(0.047)	(0.019)	(0.032)	(541)

Source: Greene, Rose, and Chen 1980

HGDM SUBMODEL NAME: VEHICLE EFFICIENCY MODEL

HGDM maintains the fleet composition, by state, by 6 vehicle classes, 6 technology (engine) types, and 18 vehicle age groups (vintages). This model contains the engineering relationships necessary to develop fleet-weighted, harmonic mean fleet fuel efficiencies at various levels of aggregation. Fleet fuel efficiency should account for the relative usage of vehicles having different fuel efficiencies. Many models calculate relative usage by estimating VMT by each vehicle type. HGDM has relative usage as a function of the fleet composition and the declining use of vehicles with age. The HGDM formulation incorporates three simplifying assumptions: (1) all vehicles of a particular vintage are driven the same number of miles annually; (2) the declining use of vehicles with age is constant across vehicle classes; and (3) the vehicle use/age relationship is independent of where the vehicle is driven.

State-level vehicle fuel economies (by class, engine type, and vintage) are determined by the calculation of national average on-the-road fuel economies and the subsequent modification by state-level "correction factors". The national average on-the-road fuel economies are modified EPA measured fuel economies. State correction factors account for variations in operating conditions. The conditions incorporated into the model are ambient temperature, trip lengths, and urban/rural driving split.

HGDM SUBMODEL NAME: GASOLINE DEMAND MODEL

The Gasoline Demand Model estimates household gasoline demand at the state level. Gasoline demand is estimated as a function of economic, demographic, environmental and vehicle stock variables. The double log equation was estimated using a variance components form of the generalized least squares technique. The equation is:

$$
\begin{aligned}
\text{GSALES} = {} & -0.1396\ (\text{PRICE}) + 0.3564\ (\text{HHINC}) \\
& - 0.04722\ (\text{YPOP}) + 0.03991\ (\text{SMCARS}) \\
& + 0.1556\ (\text{LGCARS}) + 0.03025\ (\text{LTRUCKS}) \\
& - 0.04918\ (\text{URBAN}) - 0.04982\ (\text{POPDEN}) \\
& - 0.7705\ (\text{MPG}) + 0.5715\ (\text{MAINCST}) \\
& + (\text{STATE INTERCEPT TERM})
\end{aligned}
$$

where:

GSALES = gasoline demand divided by number of households

PRICE = [(gas price) + (% no lead) x (leaded and unleaded price differential)]/(cost of living index)

HHINC = household income

YPOP = population under 18 divided by population

SMCARS = stocks of class 1 and 3 (small cars) vehicles per household

LGCARS = stocks of class 2, 4, and 5 (large) vehicles per household

LTRUCKS = stocks of class 6 vehicles (light trucks) per household

URBAN = population in SMSAs divided by population

POPPEN = population divided by area of the state

MPG = miles per gallon

MAINCST = maintenance cost (in 1967 dollars) divided by a cost of living index

STATE INTERCEPT TERM = scales result to particular state

State values for some of the variables and state intercept terms produce the state-level estimates of gasoline demand per household. These values can then be combined with household population estimates to produce aggregate gasoline demand.

HGDM SUBMODEL NAME: FUELS AND TECHNOLOGY ASSUMPTIONS MODEL

This model disaggregates the forecast light-duty vehicle "gasoline" demand into state-level fuel demand by vehicle class and engine type. This disaggregation is accomplished by using the state-level gasoline demand forecast from the Gasoline Demand Model, the on-the-road fuel efficiencies (state-level fleet, vehicle class and engine type) from the Vehicle Efficiency Model, and a measure of relative usage of vehicles by class and technology (engine) type. The relative usage measure is determined by user specified assumptions concerning usage of vehicles of a particular technology. Model users must also input assumptions concerning the market penetration of particular technologies into vehicles of each class.

From this information, the model calculates fuel demand and VMT by vehicle class and engine type for state, regional, and national levels of aggregation. Note that vehicle miles traveled is determined from fuel demand rather than the reverse, as is characteristic of most other models.

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Strategic Environmental Assessment System (SEAS)

Overview of Model

SEAS is a system of models linked to a national econometric model that includes a 200-sector input-output (I-O) model. The I-O model is the Interindustry Forecasting Model of the University of Maryland (INFORUM), and it provides forecasts for the output of 200 sectors of the economy as well as GNP and its components. Since INFORUM was not designed to estimate energy consumption and pollution emissions, SEAS provides procedures to further disaggregate these 200 sectors by process or product. Approximately 400 additional sectors result from this disaggregation.

The other models in the system use the economic forecasts to estimate pollutant levels and associated abatement costs, energy demands and supplies, transportation demands, and other variables needed to assess the environmental and economic impacts of pollution and its abatement.

Uses

SEAS has been used both inside and outside the two principal developing agencies, the U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE). Within the EPA it has been used in studies of water quality, industrial sludge, regional technology assessment, and strategic analysis related to long-term environmental trends. In DOE, the model has been used to develop the Annual Environmental Analysis Report, a technology assessment of solar energy, regional issue analysis studies, and several studies of the environmental implications of alternative energy supply and demand scenarios. The Council on Environmental Quality used it to project regional pollution levels. SEAS has also been used in a study of energy conservation measures.

Input

SEAS requires the economic and demographic assumptions used for INFORUM, regional economic data, emissions data, engineering cost data, resources data, energy data, and technological and process data.

Output

The model output includes pollution levels, abatement costs and benefits, energy demands, solid waste and associated recycling levels, land use requirements, mineral use and virgin stock status, processed ore inventories, transportation demand, and relative commodity price changes.

Transportation Component

The transportation component of SEAS is the Transportation Energy Conservation Network (TECNET).

TRANSPORTATION ENERGY CONSERVATION NETWORK (TECNET) (79-020, 79-309)

Overview of Model

The original purpose of TECNET was to estimate the impacts of energy conservation policies on transportation activity. Six interdependent models forecast direct and indirect energy requirements, and pollution emissions. These models (diagramed in Figure 5) are:

- INFORUM (a large input-output model used to forecast values for macroeconomic variables);
- TRANS (used to estimate direct energy requirements and pollution emissions of the transportation sector by travel mode, for example, auto, bus, air);
- EMBODEN (used to estimate indirect energy requirements of the transportation sector);
- ENERGY (used to estimate the direct energy demanded by nontransportation sectors of the economy);
- RESGEN (a model for the estimation of point source pollution emissions); and
- TECSET (a "preprocessor" that feeds user-specified scenario parameters into the TECNET system).

TECNET's usefulness in policy analysis has been limited by a number of factors identified in a recent proposal to revise TECNET (MITRE and CONSAD 1979). These factors are: the large number of exogenous inputs required by the model, the model's lack of sensitivity to economic and technical changes, and an outdated data base.

The proposal to revise TECNET was sponsored by the Policy Analysis Division of the U.S. Department of Energy's Office of Environment.
This section closely follows the text of the report of those revisions (MITRE and CONSAD 1979). The revisions center on the TRANS model (and its need for user-supplied parameters through TECSET), and, in keeping with the usage of the authors of the revision, references to TECNET in the rest of this section should be considered to refer more specifically

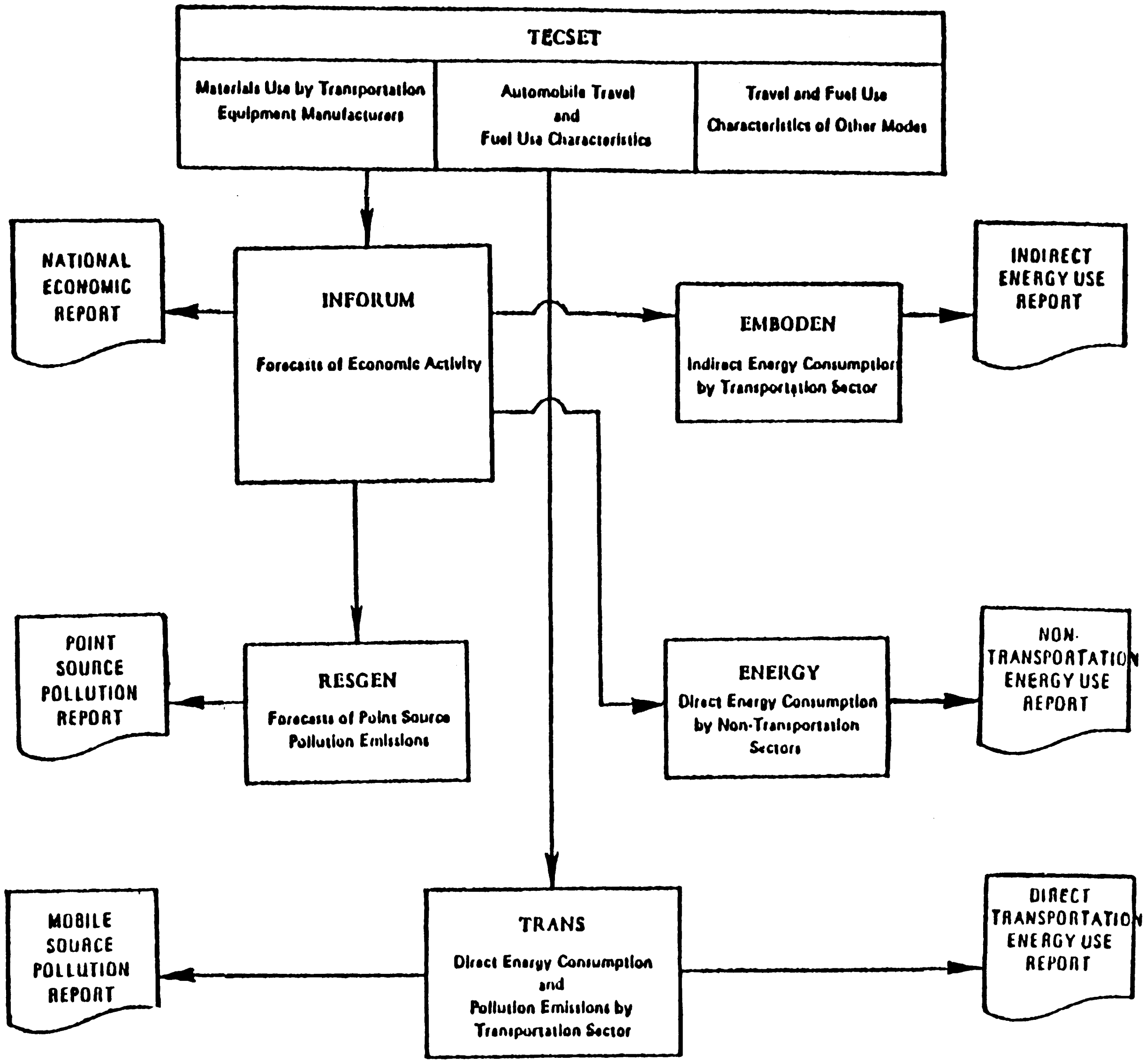

Figure 5
Simplified Diagram of TECNET

Source: Doggett et al. 1979

to TRANS. As the proposed revisions are extensive and fundamental, this section will only briefly sketch the outlines of TECNET (TRANS) before focusing on the revisions.

Modeling Structure and Technique

An overview of the original TECNET is presented in Figure 6. TECNET can be divided into submodules arranged according to three stages of analysis: modal use, modal energy consumption, and modal emissions. TECNET is unusual in that it explicitly projects passenger miles traveled (PMT) before vehicle miles traveled (VMT). Other automobile-oriented policy models do not deal directly with PMT, but relate VMT to the stock of automobiles. In the original TECNET, the automobile stock algorithm essentially allocates VMT among automobile size classes based on externally specified new-car sales distributions and age-specific scrappage rates.

The basic purpose of the revisions is to make TECNET more sensitive to potential transportation and energy policies, as well as to economic and technological variables. The revisions can be categorized into five areas: (1) demand for personal travel, (2) automobile stock, (3) emissions, (4) energy consumption, and (5) energy use and emissions from light-duty vehicles (See Figure 7).

1. **Proposed improvements to the demand for personal travel forecasts.** The exogenous input requirement of TECNET is reduced by internalizing the dependence of travel demand and modal choice on both monetary and time costs of travel. Improving the model's cost sensitivity enables it to simulate a gasoline shortage by means of a "shadow price" that includes the costs of queuing and uncertainty. The linkages and feedbacks diagramed in Figure 6 ensure some consistency between the auto stock and auto travel forecasts, and the fuel economy projections and fuel costs in the transportation demand equation.

The proposed design projects PMT, and then derives VMT from PMT. Two types of travel are distinguished: intercity and local. For each travel type, two purposes are distinguished: work-related and personal. PMT forecasts are made for each of these four cases. Modal split equations are then used to allocate the forecast PMT. The statistical estimation technique used is ordinary least squares. Due to a lack of detailed data, the historical PMTs had to be disaggregated judgmentally by trip type for use in the regressions. The equations are listed below ith definitions following, as they were presented in the draft documentation. In three of the four cases for modal split, logit

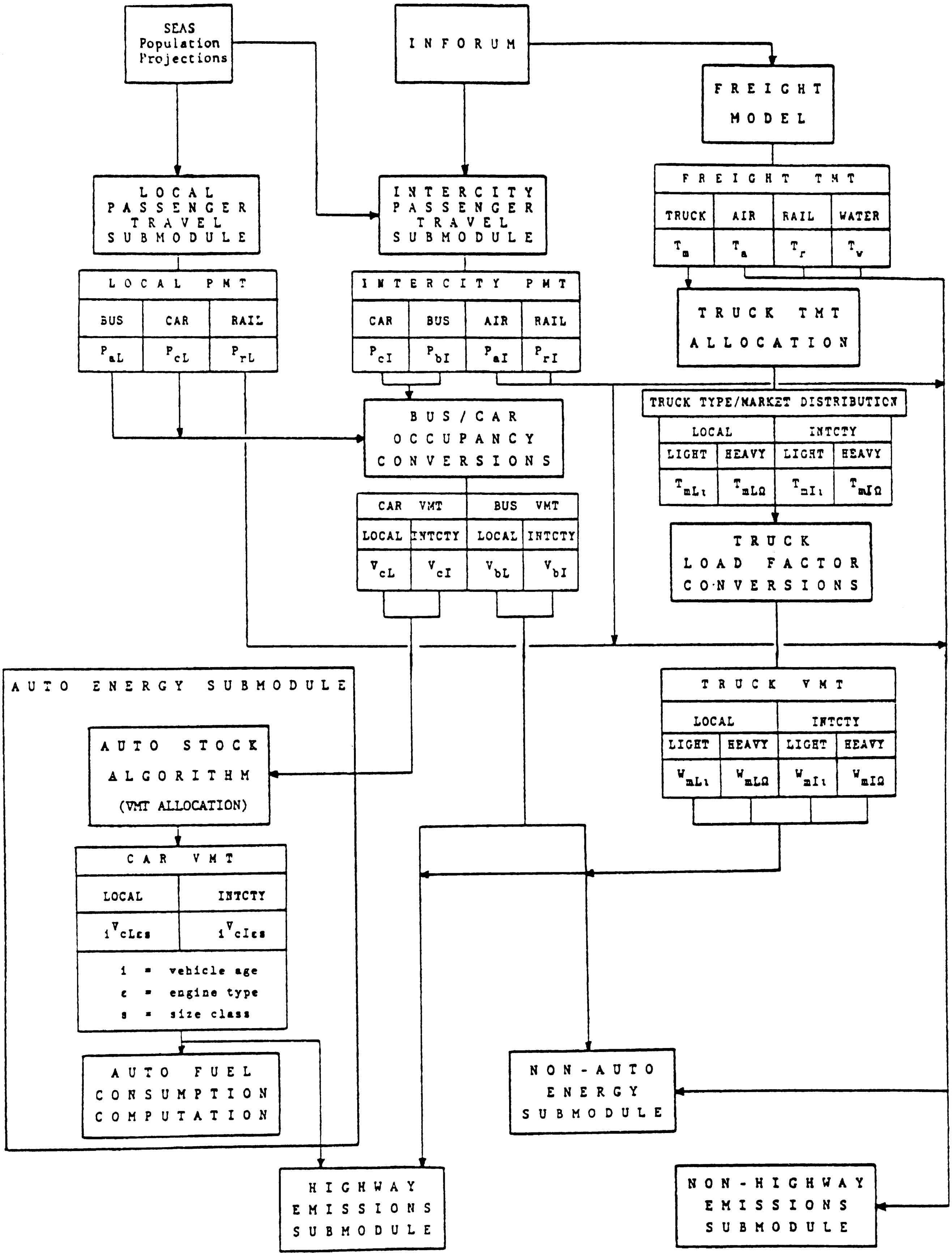

Figure 6
Overview of the Existing TECNET Model

Source: MITRE and CONSAD 1979

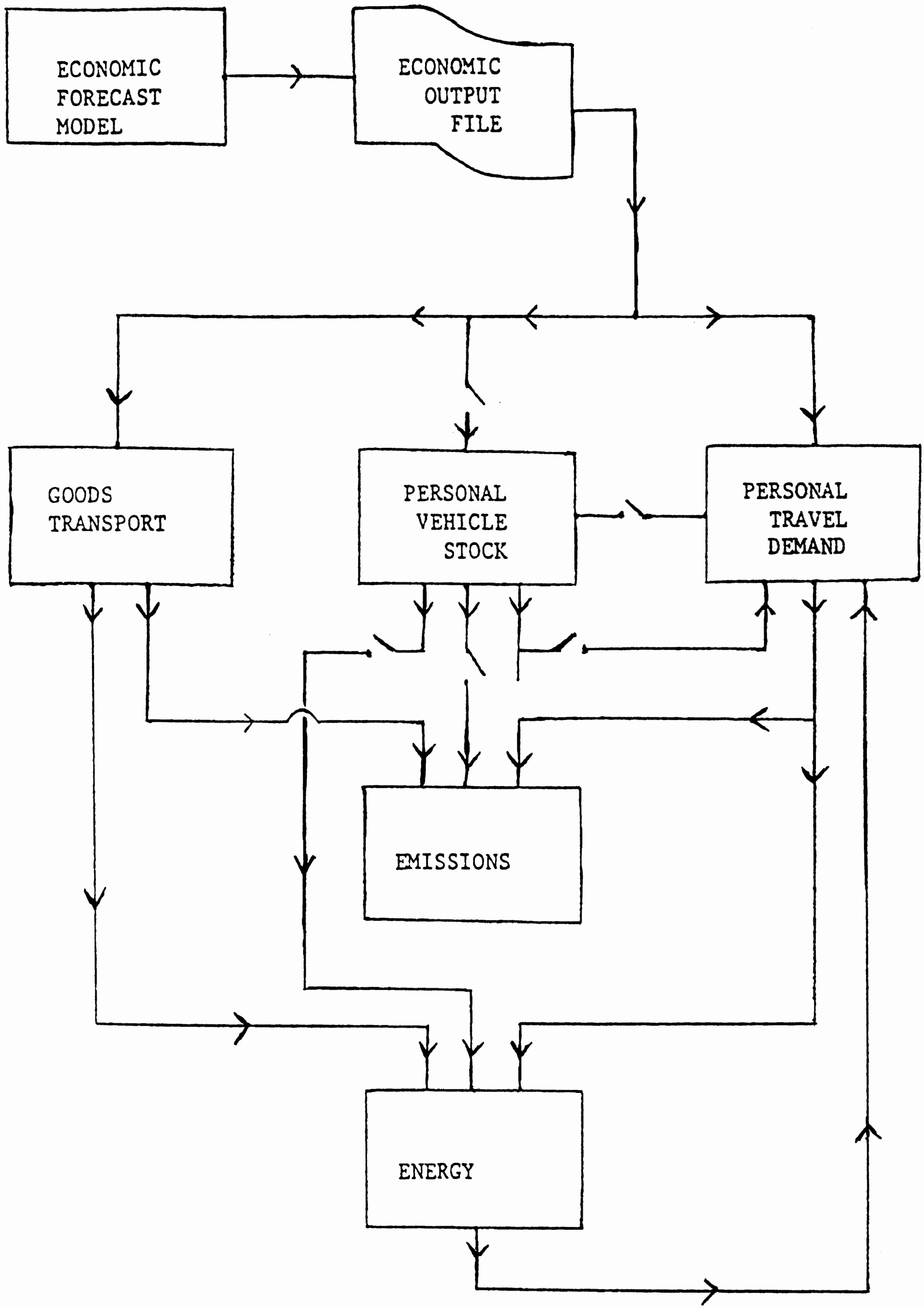

Figure 7
Simplified Flow Schematic of the Revised TECNET Design

Source: MITRE and CONSAD 1979

equations were estimated as linear equations, with the dependent variable being the logarithm of the ratios of PMTs to a numeraire PMT. The numeraire mode is derived by subtracting the other shares from one. PMT for local work-related travel (equation 11) was not econometrically estimated. Instead it is based upon the conclusion that a relatively unchanging time budget exists for such travel (Zahavi 1979).

The TECNET Personal Travel Equations

Intercity Work-Related

Total Passenger Miles:

$$PMTIW = e^{-33.2471} \times \underset{(20.4)}{LF^{3.56685}} \left(CPPMIWT + \frac{PCDI}{16xVIW}\right)^{\underset{(3.9)}{-0.860966}} \quad (1)$$

$R^2 = .996$

Modal Splits:

Personal Vehicle (driver and passengers):

$$PMTIW1,2 = PMTIW - PMTIW3 - PMTIW4 - PMT1W5 \quad (2)$$

Bus:

$$PMTIW3 = \exp[\underset{(4.6)}{1.488} - \underset{(-2.1)}{599.19} \; (1/\Sigma xj)] \quad (3)$$

$R^2 = .837$

Train:

$$PMTIW4 = \underset{(7.8)}{e^{5.66}} \; (\Sigma xj/LF)^{\underset{(5.6)}{-2.02}} \quad (3)$$

$R^2 = .873$

Plane:

$$PMTIW5 = e^{-8.1186} \times \underset{(8.3)}{V5^{1.6372}} \times \left(\frac{\Sigma xj}{LF}\right)^{\underset{(3.2)}{0.9453}} \times \left(\frac{CPPM5}{CPPMIWT1}\right)^{\underset{(0.94)}{-0.806}} \quad (5)$$

$R^2 = .993$

Intercity Personal

Total Passenger Miles per capita:

$$\frac{PMTIP}{POP} = -35.689 + \underset{(12.4)}{5.051} \; [\ln(PCDI)] - \underset{(1.63)}{0.85167} \; [\ln(CPPMIPG + \frac{PCDI}{40xVIP})] \qquad (6)$$

$R^2 = .978$

Modal Splits:

Personal Vehicle (driver and passengers):

$$PMTIP1,2 = PMTIP - PMTIP3 - PMTIP4 - PMTIP5 \qquad (7)$$

Bus:

$$\frac{PMTIP3}{PMTIP1,2} = \exp[-3.73344 - \underset{(1.47)}{0.12500} \; (CPPMIP3 - CPPMIPG1) + \underset{(8.3)}{5.4199} \times 10^6 \; (PCDI)^{-2}] \qquad (8)$$

$R^2 = .868$

Train:

$$\frac{PMTIP4}{PMTIP1,2} = \exp[-4.5043 - \underset{(3.1)}{0.44109} \; (CPPMIP4 - CPPMIPG1) + \underset{(10.2)}{1.8679} \times 10^7 \; (PCDI)^{-2}] \qquad (9)$$

$R^2 = .927$

Plane:

$$\frac{PMTIP5}{PMTIP1,2} = \exp[-2.4867 - \underset{(2.7)}{0.12616} \; (CPPMIP5 - CPPMIPG1) - \underset{(3.2)}{1.0567} \times 10^7 \; (PCDI)^{-2} + \underset{(2.8)}{3.4156} \times 10^{-3} \; (V5)] \qquad (10)$$

$R^2 = .985$

Local Work-Related

Total Passenger Miles:

$$PMTLW = 0.2135 \; (VLW) \; LF \; (1 - RU) \qquad (11)$$

Modal Splits:

Personal Vehicle (driver only):

$$\frac{PMTLW1}{PMTLW2} = \exp[1.1612 + \underset{(4.7)}{0.50652} \left(\frac{PCR}{POPDR}\right) - \underset{(6.9)}{39012} \left(\frac{CPVMLWT1}{PCDI}\right)] \quad (12)$$

R^2 = .960

Personal Vehicle (passengers):

$$PMTLW2 = PMTLW - PMTLW1 - PMTLW3 - PMTLW4 \quad (13)$$

Bus:

$$\frac{PMTLW3}{PMTLW2} = \exp[0.7016 + \ln(TBA) - \underset{(3.7)}{0.04774} (CPPMLW3 - CPPMLWG1) \quad (14)$$

$$- \underset{(4.0)}{1.775} \left(\frac{PCR}{POPDR}\right) - \underset{(2.7)}{4.768} (DTW3,1)]$$

R^2 = .970

Heavy Rail:

$$\frac{PMTLW4}{PMTLW2} = \exp[\underset{(-9.6)}{-0.426} + \ln(HRA) - \underset{(1.70)}{0.05468} (CPPMLW4 - CPPMLWG1)$$

$$- \underset{(-2.1)}{0.906} \left(\frac{PCR}{POPDR}\right) - \underset{(-1.20)}{1.230} (DTW4,1)]$$

R^2 = .863

Local Personal

Total Passenger Miles:

$$\frac{PMTLP}{POPxVLP} = \exp[\underset{(-10.0)}{-1.3866} - \underset{(-12.6)}{2495.3} (1/PCDI) - \underset{(-0.91)}{0.042} (CPPMLPG)] \quad (16)$$

R^2 = .925

Modal Splits:

Personal Vehicle (driver and passengers):

$$PMTLP1,2 = PMTLP - PMTL3 - PMTLP4 \quad (17)$$

Bus:

$$\frac{PMTLP3}{PMTCP1,2} = \exp[6.274 - \underset{(6.6)}{0.12363}\,(CPPMLP3 - CPPMLPG1) \qquad (18)$$

$$- \underset{(7.2)}{4.5666}\,\left(\frac{PCR}{POPDR}\right) - \underset{(1.36)}{5.5147}\,(DTP3,1)]$$

$R^2 = .981$

Heavy Rail:

$$\frac{PMTLP4}{PMTLP1,2} = \exp[-3.405 - \underset{(2.0)}{0.12508}\,(CPPMLP4 - CPPMLPG1) \qquad (19)$$

$$- \underset{(6.7)}{3.129}\,\left(\frac{PCR}{POPDR}\right) - \underset{(1.04)}{1.658}\,(DTP4,1)]$$

$R^2 = .957$

where t-statistics are in parentheses, and

CPPMxyz = cost per passenger mile (in cents) specific to travel type or mode

CPVMxyz = cost per vehicle mile (in cents) specific to travel type or mode

DTxy,z = difference in local travel time during peak or off-peak (P) periods as specified by the x following the letter T, between the two modes specified by the numbers y and z separated by a comma. This difference is evaluated for a trip of average length DWy or DPy; the expression is

$$DTxy,z = Dxy\left(\frac{1}{VLxy} - \frac{1}{VLxz}\right)$$

G = following CPPMxy, means that car cost includes only the cost of fuel

I = intercity

L = local

LF = labor force (in 10^6)

PCR = stock of personal vehicles (in 10^6)

P = personal

PCDI = per capita disposal income (in 1972 dollars)

PMTxyz = passenger miles traveled per year (in 10^9)

POP = total population

POPDR = population of driving age (17-74)

RU = rate of unemployment (expressed as a fraction)

TBA = percent of population having access to bus transit

HRA = percent of population having access to heavy rail transit

T = following CPPMxy or CPPMxyz, means that car cost includes the cost of fuel and the capital cost

Vxyz = travel velocity (mph) by travel type or mode; symbols for xyz are left out when no ambiguity results

W = work related

Σxj = sum over INFORUM service sector inputs

1 = car (driver only)

1,2 = car driver and passengers

2 = car (passengers only)

3 = bus, trolley and light rail

4 = train in intercity travel, heavy rail in local travel

5 = plane

2. **Proposed improvements to the auto stock forecasts.** The amount of travel, the vehicle emissions and energy coefficients, and the size and composition of the auto stock together determine the energy consumption and pollution emissions related to autos. For this purpose, portions of the Sweeney Passenger Car Gasoline Consumption Model (presented above) are incorporated into TECNET by borrowing the equations for new-car purchases, survival rates, and relative utilization rates. The new-car-purchase equation is:

$$NPCR = POP \times e^{\left[\underset{(4.5)}{16.993} - \underset{(3.8)}{3.02}\left(\ln\left[\frac{ESLO}{POP}\right]\right) + \underset{(3.5)}{2.325}\left(\ln\left[\frac{YD72}{POP}\right]\right) - \underset{(1.4)}{0.479}\left(\ln[PG]\right) - \underset{(1.4)}{.786}\left(\ln[PCAR]\right) - \underset{(4.0)}{.049}(RU)\right]} \tag{20}$$

$\bar{R}^2 = .82$

where t-statistics are in parentheses, and

NPCR = new-passenger-car registrations

POP = total U.S. population

ESLO = effective stock of passenger cars left over from the last period

YD72 = total personal disposable income in 1972 dollars

PG = the average retail price of gasoline, deflated by the overall Consumer Price Index (CPI)

PCAR = the relative price index for new cars, given by the ratio of the CPI for new cars to the overall CPI

RU = the unemployment rate, in percent

Purchases (new registrations) are a function of effective stock (ESLO) which is the auto stock adjusted for age composition. ESLO is calculated so that older cars add less to the effective stock than newer cars:

$$ESLO_t = \sum_{i-\infty}^{t-1} NPCR_i \times SU_{it} \times GAMMA^{(t-1)} \tag{21}$$

where:

ESLO = effective stock of passenger cars left over from the last period

SU = survival fraction

GAMMA = relative utilization (to account for declining utilization with age)

i = vintage

t = year

Equations (20) and (21) are linked to the travel forecast through the survival fraction (SU), which is an econometrically estimated function of vehicle age and cumulative miles traveled:

$$\ln\left(\frac{SU_{it}}{1-SU_{it}}\right) = -0.078\ (CM_{it}) + D_i \tag{22}$$

where:

SU_{it} = survival fraction

CM_{it} = cumulative miles traveled by vehicles of age i in year t

D_i = dummy variables estimated for vehicles of age i, i = 2 to 15

The new-car-purchase equation (20) from the Sweeney model produces forecasts of passenger cars only. To forecast all personal vehicles, including light trucks, the equations' results are scaled up by TECNET:

$$NPCRT = 1.17\ (NPCR) \tag{23}$$

where NPCRT = new passenger-car and personal-truck registrations

Once the number of vehicles by vintage has been calculated, the following Sweeney equation is used to calculate average annual miles per vehicle by vintage:

$$VMMY = V_1 \times GAMMA^{AGE} \qquad (24)$$

$$= 16.56 \times 0.921^{AGE}$$

$R^2 = .84$

where VMMY = average annual miles per vehicle by vintage

The linkages diagramed in Figure 7 attempt to provide for consistency between travel and vehicle stock forecasts. Key travel equations include vehicle stock per person of driving age as explanatory variables. On the stock side, travel affects survival rates. A safeguard is to be provided in the model that alerts the user if annual miles per vehicle differ from the base year by more than ten percent. An adjustment algorithm can then be used to eliminate the discrepancy.

The emissions and energy calculations require market shares for three vehicle categories in order to track the corresponding proportions in vehicle stock and VMT. These categories are: domestic passenger cars, imported passenger cars, and personal light trucks. These shares are treated as exogenous inputs to TECNET. The default values provided are derived from the average over 1975, 1976, and 1977 with the passenger car-light truck split determined first by the model authors' "best guess." The shares are presented in Figure 8.

3. Proposed improvements to emissions forecasts. To attempt to improve the accuracy and completeness of the emissions factors used to estimate modal emissions, adjustments to these factors are to be made to reflect air conditioning usage, ambient temperature, evaporative emissions, and more. Additionally, the model is to be made sensitive to user-varied assumptions about inspection/maintenance programs, tampering, deterioration, and related aspects of emissions control.

4. Proposed improvements to energy consumption forecasts. The basic energy calculation is the transition from VMT for a particular vehicle to gallons of fuel consumption. This calculation requires: (1) the grouping of vehicles into appropriate fuel consumption classes, and (2) the estimation of fuel efficiencies for these classes. The model authors anticipate providing the user with three alternative approaches.

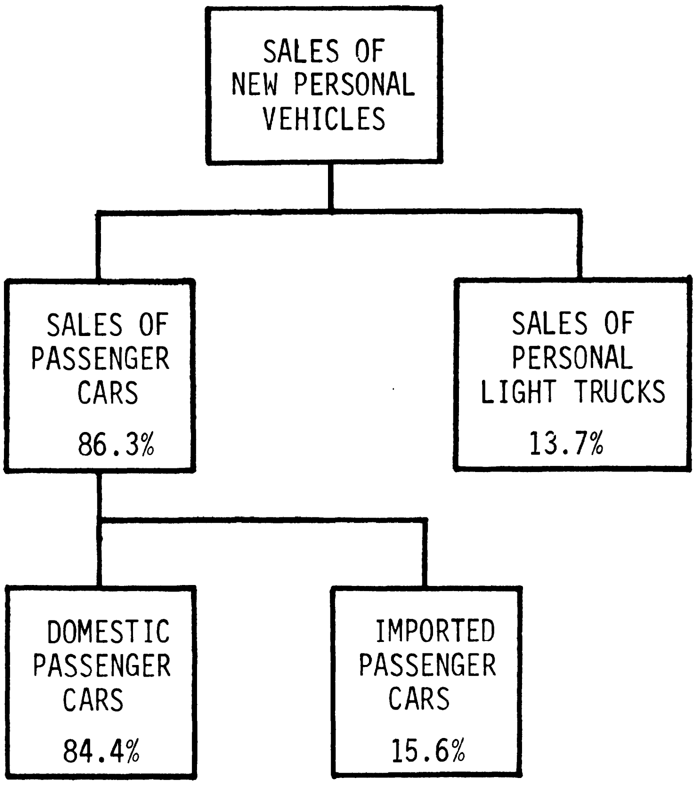

Figure 8
Market Share Categories for Personal Vehicles with 1977 Estimates
Source: CONSAD Corporation

The first approach derives fuel efficiency coefficients from Corporate Average Fuel Economy (CAFE) standards. Estimated domestic passenger-car fuel economy is set equal to some constant times the CAFE. The default value of this constant is 1.05. The resulting EPA-based gallons-per-mile figures are adjusted to correspond to on-the-road values. The fuel economy of imported cars is calculated by the same procedure except that the default value of the constant is increased (1.5 in 1980, 1.3 in 1985). Post-1980 fuel economies are calculated on the basis of assumptions about the extension of current regulations.

The second approach uses the higher of the two alternatives: (1) CAFE standards and (2) the Sweeney equation for the relationship between gasoline price and fuel economy:

$$\ln(MPG) = 3.4096 + .72148\ [\ln(PG_{t-2}/CPI)]\ .278516\ [\ln(EFF)]$$

where:

MPG = an estimate of on-the-road miles per gallon for all new passenger-vehicle sales in a given year. For use in this model this term is defined as the inverse of sales-weighted average of gallons per mile (GPM) coefficients adjusted to reflect an estimate of actual mpg for domestic passenger cars and imported passenger cars.

PG = price of gas, average for year prior to model year, in 1967 dollars

EFF = term used to measure changes in mpg per vehicle weight relative to 1974 as the base year

The Sweeney equation was estimated with 1957-1974 data, a period of relative gasoline price stability. However, the equation implies substantial price responsiveness. A gasoline price of 1.25 (in 1979 dollars) implies that the CAFE standard of 20.5 mpg for 1980 will be exceeded, while a price of two dollars implies a new-car fleet average (EPA-based) fuel economy of 41 mpg. The model authors recommend modification of the Sweeney model to include supply constraints, and default values of these are given.

The third approach is to allow the user to input vehicle mixes and associated fuel economies.

An additional improvement to TECNET is the provision to account for five fuel types in calculating fuel consumption: leaded and unleaded gasoline, diesel, and two alternate fuel types. Diesel fuel use is assumed to be 25 percent more efficient per gallon than gasoline. Overall fleet mpg for a model year is an average of mpg ratings by fuel type, with market shares as weights.

5. **Proposed improvements to energy use and emissions forecasts for light-duty diesel vehicles.** TECNET did not have any provisions for diesels; thus revisions are proposed to develop estimates of diesel market penetration, energy use, and emissions. Due to the uncertainties imposed by potential government regulation and technological innovation, user input of market penetration assumptions is provided for by the model authors.

Input

The revised TECNET model is intended for either "stand alone" use, or use as part of the SEAS model system. TECNET requires projections of various economic and demographic data. It is anticipated that INFORUM will be used for this purpose, although other macroeconomic models or demographic projections may be used. In addition, there are other exogenous variables for which either user-specified or default values may be used, including demographic projections, government expenditures, disposable income, timing and stringency of government regulations, and rate of penetration of technological innovations.

Output

The model forecasts passenger travel demand, personal vehicle sales and stock, goods transport, vehicle emissions, and vehicle energy consumption. Travel demand is disaggregated by mode, and energy consumption is disaggregated by fuel type.

Comments

Programming of the revisions is scheduled for August 1980.

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SRI-Gulf and Derivative Models

Overview of Models

This section presents the class of dynamic general equilibrium models which includes the SRI-Gulf Energy Model (73-261), General Equilibrium Modeling System (GEMS) (77-283), Livermore Energy Policy Model (EPM/LLL) (78-462), and Long-term Energy Analysis Program (LEAP) (77-286). They use a network iteration algorithm to dynamically compute equilibrium prices and quantities for energy resources and products. Figure 9 illustrates the relationships among the models.

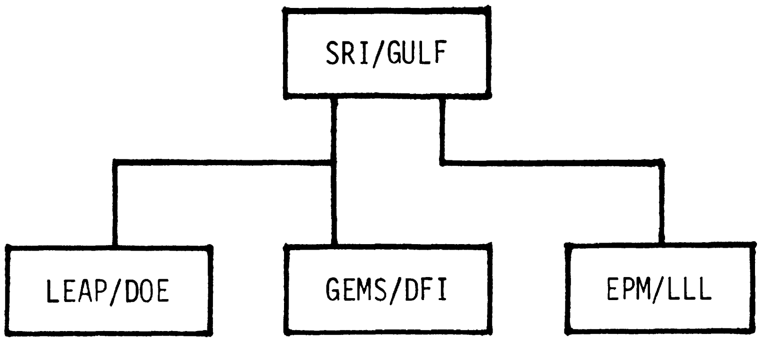

Figure 9
Relation of the Dynamic General Equilibrium Models

The methodological description presented below is that of the SRI/Gulf model. While each of the other models has the same general methodology, EPM/LLL, GEMS and LEAP contain modifications and enhancements developed for their different needs and purposes that are discussed in later sections.

Uses

This class of models can be used for forecasting, comparison of the long-run impacts of various future energy scenarios, evaluating technology, or policy analysis.

Modeling Structure and Techniques

These generalized equilibrium models are built as networks that trace the flow of energy from resource markets to end-use demands. (For an example of a network, see Figure 10.) The methodology, termed generalized equilibrium modeling, is a combination of econometric methods, optimization or programming methods, general competitive equilibrium models, and simulation methods. The models have these basic elements: (1) processes describing the fundamental submodels; (2) a network describing the interactions or links among the processes; and (3) an algorithm for determining the numerical values of all of the variables in the model. A process is a set of economic and/or subjective relations or equations that may represent an entire national economic or natural system or a fundamental technology or decision-making process. Processes generally contain physical and/or behavioral relations. The algorithm finds the set of prices and quantities that satisfies the relations embodied in the processes and their linkages in the network. Prices and quantities, the links between the nodes, are successively adjusted in a series of iterations in each time period to produce an equilibrium solution. The algorithm does not impose arbitrary restrictions on the solution to ensure convergence. Instead, a relaxation methodology is used to dampen oscillations.

A number of end-use demands and geographic regions may be modeled. Supply of resources by regions and their depletion over time is modeled. Estimates of future prices of primary resources are used to determine economic rent on resources in earlier time periods.

The SRI-Gulf model designates inputs, outputs, and the algorithms associated with each node. A parameter file has all the information needed for the algorithm assigned to a node. The types of algorithms that can be used are conversion processes, resource extraction processes, market allocation nodes, and special models (electric power plants, refinery, and capital equipment supplier). Some of the SRI-Gulf class models, LEAP for instance, allow bounds or constraints to be placed on the solution of each process algorithm. For more detailed descriptions of the algorithms see papers by Rousseau et al. (1978b) and Cazalet (1977).

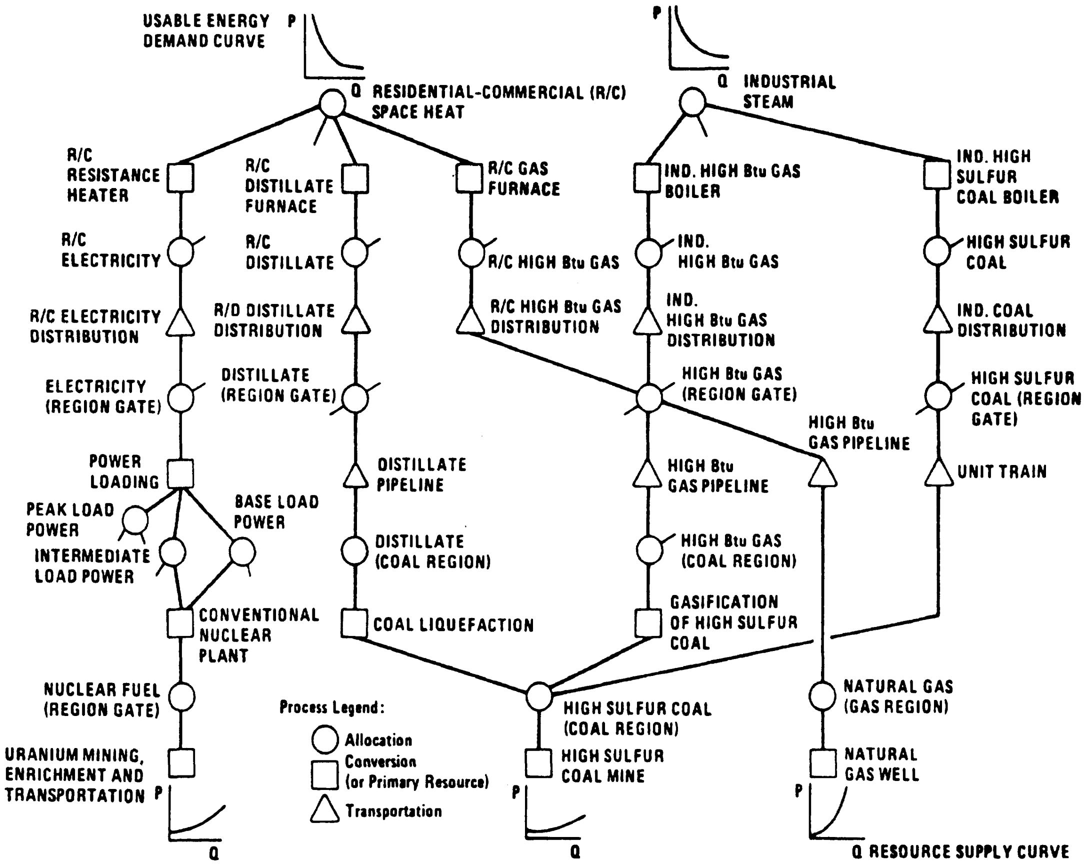

Figure 10
Schematic Diagram of the Network Structure of the SRI-Gulf Model
Source: Cazalet 1977

The output from the model includes input and output prices and quantities for each node over the time period in question. Some versions have graphing capabilities for prices and quantities. Calculations in the model are performed by moving either "up" to determine prices or "down" to allocate quantities. Each node in the process is thus connected with two algorithms. The algorithm associated with a downward iteration is a physical relation. The algorithm associated with an upward iteration is a behavioral relation (given costs, the price that will be charged for an output is calculated).

At the bottom of the network are resource nodes. Given an initial resource output, the algorithm, on an upward iteration, calculates an output price. To do so, it needs as input a marginal cost curve of resource supply, a rate of discount and other technological parameters. Allowing for economic rent, the resource owner sets a price that maximizes his discounted present value.

Moving from a resource node, the energy resource must be transported via a transport node or converted by a process. In LEAP, some transportation costs are implicitly incorporated as differentials on the links. In an equilibrium situation and with perfect competition the producer will make zero economic profits (that is, a reasonable but not excessive rate of return on equity). Thus, the basic price charged will be the one that makes net present value of output equal to zero.

For a transportation process, the operating and capital costs will be a function of distance. Allowance can also be made for growth, excess capacity, secondary materials, technological change, and inflation.

From a transport node the resource can go to a conversion node. The number of inputs that a conversion node can accept depends on the model (e.g., LEAP accepts only three); inputs and secondary inputs are converted into one output. Figure 11 shows a flow chart of this type of node and input parameters necessary for an upward iteration. The basic formula for price out of a conversion node is the same as that for a transport node, where one of the costs is the cost of the inputs from the node below.

Once through a conversion node, the output could be transported to another conversion node or converted to an end-use demand or market node. End-use demand schedules, which are exogenous, can vary in elasticity. From the price of an end-use demand and the end-use demand schedule, a quantity of end-use service is computed.

If more than one energy product is competing to supply an end-use service or any node, an allocation node is necessary (e.g., when urban vehicle miles can come from gasoline, diesel fuel, or electricity). Then, the share for each fuel will be a function of share last period, relative costs of the competing fuels, and, depending on the model, a price sensitivity parameter which designates how rapidly market shares can change. The price of the end-use service in this case is a weighted average of the prices of the fuels used. Some models use quantity-

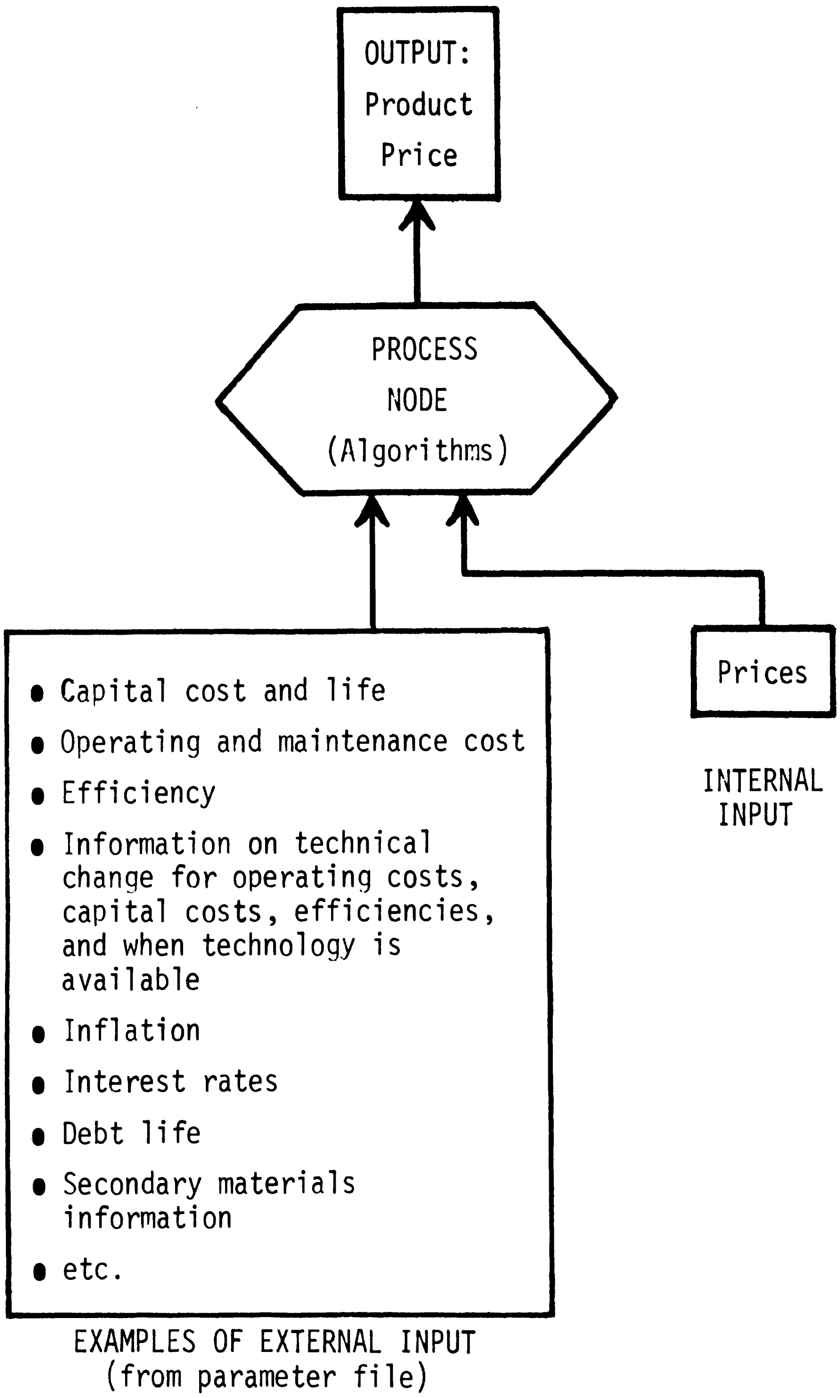

Figure 11
Basic Conversion Node on the Upward Iteration

weighted averages, others use market-share weights. The weighted average fuel price is used to calculate quantity demanded on each iteration.

Once an end-use quantity is computed, the model iterates back down the networks, using physical relations to calculate quantities at every conversion node.

Similar provisions may be made for secondary material flows, and changes in capital stock. Working back down the system, input quantities are calculated at each node. Once at the resource node, the process starts again and prices are calculated going up the network. This process continues until prices and quantities converge.

Simpler versions of basic processes may exist, with no capital costs, or with no operating, maintenance, or capital costs.

Several constraint nodes may be available. Outputs can be restrained to a fixed ratio. There can be price or quantity constraints. Government regulations can be simulated by representation as costs or the elimination of nodes from the network.

There can be special process models in the system. In the SRI/Gulf model, one group simulates electric power production, by combining up to five inputs in specified proportions, and allowing the outputs to represent different load factors. One combines several conversion processes to model a refinery, and another models the secondary material or capital equipment supplies industry. The latter is not true of the GEMS/DFI or LEAP models.

Relationship to Other Models

The earliest of these models is SRI-Gulf, a proprietary model designed to evaluate synthetic fuel policy. Lawrence Livermore Laboratory developed a more flexible regionalized version for policy analysis called the Energy Policy Model (EPM/LLL) along with a computer language to facilitate building and changing energy networks. A nonregionalized version with a number of algorithm changes and increased network flexibility, called GEMS, was developed by Decision Focus, Inc. An early version of GEMS was sold to the U.S. Department of Energy and, with their changes, has become the Long-Term Energy Analysis Program (LEAP). (For more complete explanations, see the models' specific descriptions that follow.)

Transportation Component

The transportation components of the models, which include transportation by mode, forecast the equilibrium prices and quantities of vehicle services (e.g., vehicle miles traveled, passenger air miles). When more than one type of energy (e.g., gasoline, diesel, or electricity) may be used in supplying the transportation service, the market share of each energy type used is forecast. Each transportation component is an end-use demand built into the model network, which connects the end-use demand to fuel inputs. The structure of the transport sector is the same as the general model structure discussed earlier, with the modeler supplying the parameters necessary for that sector.

SRI-GULF ENERGY MODEL (73-261)

Overview of Model

This is a national dynamic general equilibrium model with eight demand regions and thirty supply regions. It is the earliest and least flexible of the models, since the computer language does not allow networks to be easily changed.

Uses

The model was developed by SRI International to analyze synthetic fuel policy for Gulf Oil Corporation. Synthetic fuel technologies were evaluated by their impact on discounted company profits. Synthetic fuel technologies and other major energy technologies affecting Gulf's decisions were modeled in great detail. A subsequent version was used to evaluate the impacts of alternative government policies on synthetic fuels.

Input

A data base was developed internally at SRI for this model.

The basic inputs to the model are: (1) An energy network that sets up resource nodes, process nodes, demand nodes, market nodes, refinery locations or nodes, and transportation linkages; and (2) A parameter file that contains (a) Data for variables such as corporate tax rates, number of iterations, length of time period, rate of inflation, etc.; (b) Parameters for all intermediate calculations; (c) Information on each process--its type and parameters necessary for price-quantity calculations; (d) End-use demand schedules; (e) Resource supply curves; (f) Distances on regional versions; and (g) The initial quantities for the entire network.

Structure

The processes and relations of the SRI-Gulf type of models have been described above. The basic processes particular to the 1976 version of the SRI-Gulf model (Cazalet 1977) are outlined here. They can be modified to aid in the analysis of a particular problem.

- Simple Conversion Processes describe the technology and economics of converting one energy material to another (e.g., synthetic gas from coal and residential space heat from gas).
- Allocation Processes describe the allocation of demand among competing sources of supply (i.e., allocation of gas demand among alternative sources and space heat demand among alternative furnaces and fuels).
- Primary Resource Processes describe the depletion and pricing of energy resources (i.e., natural gas and coal).
- End Use Demand Processes describe the growth in demand for usable energy over time and the effect on demand of changes in prices (i.e., space heat and industrial steam).
- Transportation Processes describe technology and economics of moving an energy material from one location to another (i.e., natural gas pipelines and coal unit trains).
- Complex Conversion Processes (i.e., refineries and electric power generation).
- Secondary Industry Processes describe the impact on secondary material prices of changes in demand for secondary materials used in construction of new energy facilities (i.e., pressure vessels and surface mining equipment). (p. 4-1)

Within each basic process are two types of relations: physical and behavioral, where physical relations describe the flow of materials within a process, and behavioral relations describe the decisionmaking behavior that sets prices and quantities.

In the simple conversion process, equations are included for material flow and quantity, capacity additions and replacement, initial conditions, net present value, operating cost, product price under slow and rapid growth, growth rate, inflation and secondary materials cost adjustments, and technological change and present value of capital cost. In the allocation process, equations are included for physical flow, total quantity, new and existing quantity demanded, market share, and static and dynamic allocation of demand. In the primary resource process, equations are included for production, capacity, initial conditions, long-run marginal cost and price, inflation and technological change factors, secondary material requirements, and adjusted primary resource price. In the end-use demand process there are reference demand and price sensitive demand equations. The transportation process includes capital cost, operating cost, and thermal efficiency adjustment equations. The complex conversion process has sets of equations for electric power generation, refineries, auxiliary inputs, and joint products. The price and quantity regulation process has quantity and price regulation equalities and inequalities, and relations for allocation process market share and the regulated or unregulated conversion process. The secondary material process has equations for prices, demand to capacity ratio, and industry capacity and half-life response time.

About 2700 processes can be contained in the model at one time.

Computer Requirements

Thirty to sixty iterations are needed for convergence for a base case with poor initial estimates of prices and quantities. Ten to thirty iterations give satisfactory convergence for a sensitivity test. Each iteration of the model takes 1.3 minutes of IBM 370/168 computer time and uses about 600,000 bytes of core storage.

Transportation Component

The end-use service demand is measured in vehicle miles. The own-price elasticity of demand for automobile VMT is assumed to be a constant, -0.38. Equilibrium quantity and price of VMT are output.

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LAWRENCE LIVERMORE LABORATORY ENERGY POLICY MODEL (EPM/LLL) (78-462)

Overview of Model

EPM was developed as an improvement to the SRI-Gulf model, to provide for greater flexibility, and for the incorporation of government regulation in simulations. Lawrence Livermore Laboratory, using the structure of the SRI-Gulf model, made refinements on the microeconomics, incorporated facilities for analysis of regulation, and increased the flexibility of the model by developing a package of programs--the Economic Modeling System (EMS). EMS allows the model users to build their own networks through the use of a new modeling computer language designed to operate with EMS. Calculations are done through the year 2025.

Uses

The model was designed to be a flexible tool for policy evaluation or comparison of various energy scenarios. Possible policies and scenarios can be represented by elimination of nodes from the network, changes in costs, changes in technology, new technology, price controls, or quantity controls.

Analyses have been performed for the impacts of the introduction of electric vehicles; various energy storage systems for automobile propulsion (e.g., dual-fueled hybrids, liquid hydrogen broad-cut fuels); and fuel economy standards.

Structure

The most general kind of computational submodel, called the SIMPLE submodel, contains the following quantity computations for the process being modeled: growth per period, plant life, replacements, construction and capacity, efficiency, primary and secondary input quantities, and capital cost learning factor. Price computations include: capital cost, borrowings, equity discount and interest rates, present value of debt, equity financing, depreciation tax credit, real estate taxes and insurance, shutdown-expansion factor, capital equipment cost adjustment, present value of fixed charges, fuel cost, operating cost, present value computations, actual future and perceived operating income, and final and relaxed output price.

Input

The input data are a revision of the original SRI-Gulf data base. VMT demand elasticities were based on those of the Wharton Econometric Forecasting Associates Automobile Demand Model. The model user must describe the model network in the modeling language, and input program variables, process and market node parameters, end-use demands, resource volume estimates, initial market shares, and transportation process distances. The model may contain over 3000 nodes.

Computer Requirements

The program is operational on a Control Data Corporation (CDC) 7600 on the Livermore Time-Sharing System (LTSS). A base case analysis might be expected to take 30-40 minutes; 100 iterations of the model might take 12-15 minutes. Sensitivity analysis after the base case has been established can be expected to take half as long as the base case solution. Most of the computer code is written in FORTRAN; it is divided into four main programs, INPUT, SOLVE, PRINT, and PLOT.

Transportation Component

One end-use transport demand variable that has been analyzed is vehicle miles traveled, with the demand schedule taken from the Wharton EFA Automobile Demand Model. Transportation fuels is one of 21 categories of model output.

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GENERALIZED EQUILIBRIUM MODELING SYSTEM (GEMS) (77-283)

Overview of Model

GEMS is a nonregionalized version of the general equilibrium SRI-Gulf Energy Model. It is a software system and collection of component processes that can be used to custom-build an energy-economy network. The specific networks built depend on the client for whom it is being used.

Uses

Clients for whom GEMS network models have been built include Chase Manhattan Bank, the Electric Power Research Institute (EPRI), and the Tennessee Valley Authority (TVA).

Relationship to Other Models

The changes from the SRI-Gulf model include: changes in the data base; new software that increases flexibility and reduces data management costs; a more hierarchical structure allowing feedback from the rest of the economy; new assumptions in the process logic that keep track of capacity additions, new drilling or investment in resources, and resource production; and changes in learning assumptions.

Structure

GEMS consists of three components: (1) a system of modeling conventions that facilitates the definition of network models of economic systems that link together either macro- and micro-level process models of sectors of the economy, or specific economic activities such as crude oil refining or coal mining; (2) a basic library of generic process models that describe the physical and behavioral characteristics of basic economic activities; and (3) the DFI Model Data Management System (MDMS)', which facilitates the definition of modeling conventions in the construction of process models, and in the management of data required in an actual model.

The basic elements of a network model implemented with the GEMS include: (1) process models of individual components of the energy-economy network system, such as economic or natural systems, technologies, or decisionmaking process, containing physical and/or behavioral relations; (2) a network defining the links between the processes, with end-use demand-for-energy processes at the top of the network, primary-resource supply processes at the bottom, and market behavior, conversion, and transportation between; and (3) an algorithm that uses iterative techniques to successively adjust prices and quantities until a solution is found.

Models are constructed using a set of processes from the basic library of GEMS modules, with minor modifications. These modules simulate basic allocation, basic conversion, electric power conversion, electric power load, electric power allocation, depleteable resource, transportation, distribution, end-use conversion, end-use demand, financial, and governmental processes.

Constraints on the solution of a model, in the form of price regulation of resources, may be applied.

Transportation Component

End-use demands that have been considered in some versions include demand for urban and rural vehicle miles of travel, and penetration of electric cars into these markets.

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LONG-TERM ENERGY ANALYSIS PROGRAM (LEAP) (77-286)

Overview of Model

LEAP models the energy system of the United States from 1975 to 2020 in five-year intervals. It is capable of developing long-term energy supply, conversion, and demand forecasts at the national level. The model contains detailed aspects of fuel consumption by sector (residential, commercial, industrial, and transportation), domestic production by fuel, transportation and distribution of fuels, and import levels. The roles of new technologies including synthetic fuels, solar power, and renewable energy can be accounted for in the model. LEAP produces forecasts of the energy market, and projections of marginal prices for fuels and services, and can keep track of capacity additions.

LEAP is based on a version of the Generalized Equilibrium Model System (GEMS) that was purchased by DOE from Decision Focus, Inc. With DOE's changes the model has become LEAP. For the Annual Report to Congress 1979, DOE extended LEAP to include 225 nodes. The changes incorporated into LEAP by DOE include:

- Development of report writers. LEAP output can be displayed both in summary tables and disaggregated listings to a specified level of detail. A user can design an output report by identifying the appropriate nodes. Reports can also contain user-specified calculations of the model's output values. The current energy balance reports display energy supply and demand summaries, sources of fuels, end-use demands by sector, electricity generation, and penetration of new technologies. An associated price table can also be produced for each quantity table.
- PERUSE. A software package that facilitates the incorporation of user specified data changes into the model.
- Graphics. Graphs can be generated from LEAP solution files.

Uses

The model is used for long-term projection through 2020, and is calibrated with MEFS through 1995. Projections after 2020 are produced to avoid end-effect problems.

Input

The input data relate to the individual processes that can be grouped as follows: conversion, resource, demand, allocation, and transportation. Each process requires physical data such as quantities and technological parameters, and economic values such as cost, tax, and regulatory data.

The data come from a variety of sources such as: Midterm Energy Forecasting System (MEFS), U.S. Department of Transportation, the National Coal Model, Oak Ridge National Laboratory, Brookhaven National Laboratory, U.S. Bureau of Mines, and in-house generation.

Computer Requirements

Processor: IBM 370/168

Storage: 1500 tracks of disk storage; 2000K bytes of core for a 50 year simulation.

Language: FORTRAN

I/O mode: Disk, tape.

Average run and turn around times: 30-35 seconds of CPU time per iteration.

Transportation Component

The final transport service demands that have been analyzed include intercity and intracity vehicle miles traveled, light-truck vehicle miles, heavy-truck vehicle miles, air passenger miles, rail ton miles, bus vehicle miles, and marine ton miles. The model has also been used for an analysis of electric car introduction. The base case in that application assumed electric vehicles compete only for urban mileage, penetrate the market after 1985, and become commercially available in 1990. LEAP can also be used to analyze the effects of different automobile efficiency (mpg) assumptions and the effects of higher world oil prices.

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Brookhaven National Laboratory Modeling System

Overview of Models

For energy policy analysis and projections, Brookhaven National Laboratory (BNL) uses three models interactively. These are: TESOM, LITM, and the Input-Output (I-O) Model. The linear programming model, TESOM (BESOM and DESOM are earlier versions) solves for the energy products that minimize the total system costs of producing those products subject to energy resource, final energy demand, pollution, and energy conversion capacity constraints. The cost of a resource is exogenous unless it is represented as a stepwise supply schedule with more production at higher prices. The minimum energy product costs from TESOM are fed into the Dale W. Jorgenson Associates model, LITM. LITM (Long-term Interindustry Transaction Model) is a dynamic model with two fully integrated components: a macromodel and an interindustry model. (DGEM is a second generation LITM.) The macromodel calculates: (1) consumption, investment, government spending, and exports of goods and services for the entire U.S.; and (2) prices of labor and capital. The interindustry model in LITM calculates prices for ten producing sectors and imports. The four aggregate demand categories in LITM are disaggregated into 110 industries in the Input-Output Model by using information from the LITM interindustry model. The 110 end-use demands that encompass the whole economy are used in the I-O model to solve the total demands for energy services. These energy service demands are used as constraints in TESOM. The solution of energy production in TESOM is used to create input-output coefficients for the energy sector of the I-O Model. The three models iterate until the solutions for all three converge (see Figure 12).

Uses

Recent interactive uses of the models at BNL include (1) a cost-benefit analysis of energy policies under three scenarios: status quo, a large conservation initiative, and a major synfuels program; (2)

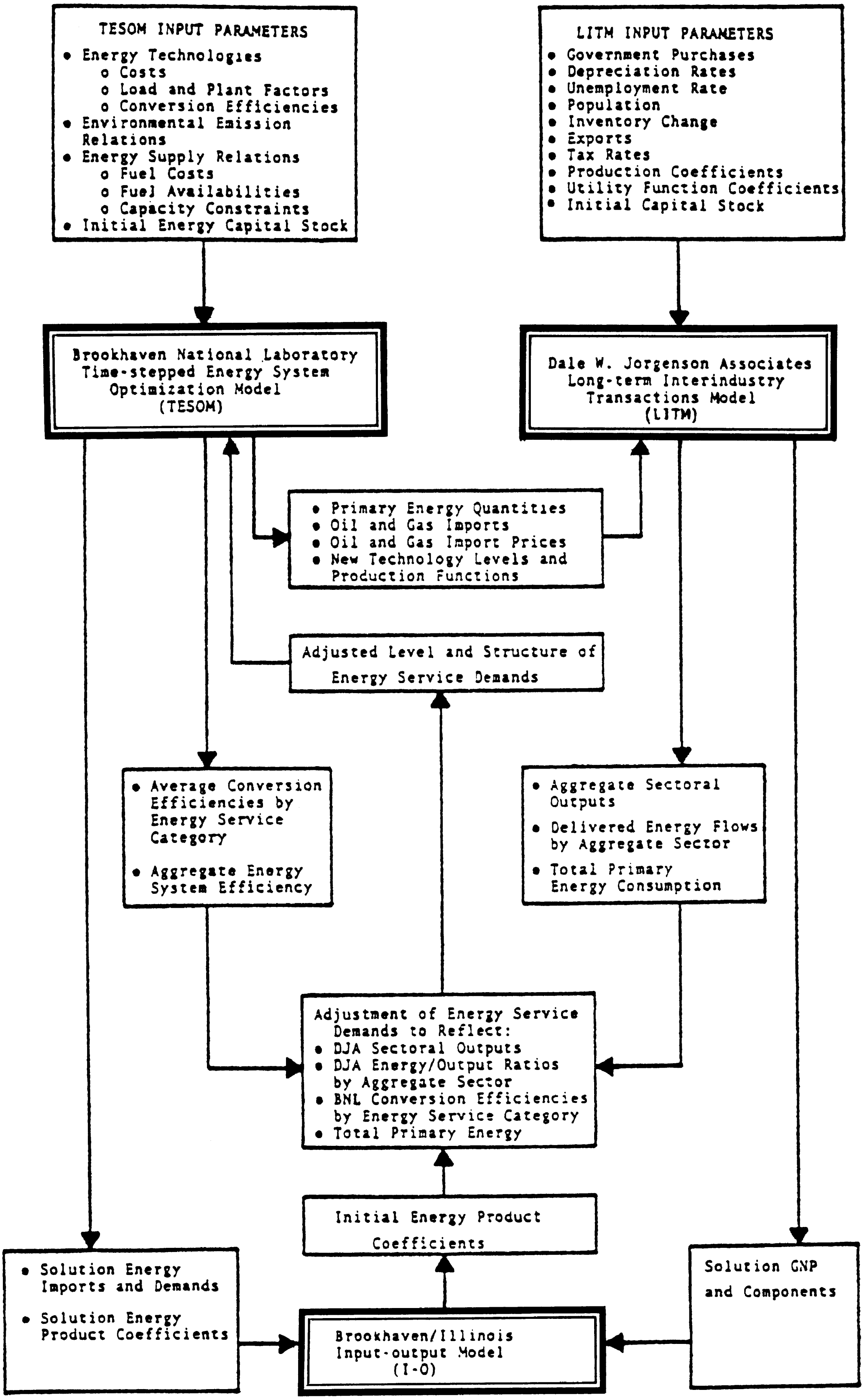

Figure 12
Brookhaven National Laboratory/Dale W. Jorgenson Associates
Combined Model System

Source: Groncki and Marcuse, 1979

comprehensive energy projections through 2025; and (3) an analysis of solar policy options.

References

Fraser, J.T. 1978. Documentation of the Brookhaven Energy I-O and I-O/BESOM linkage. Upton, N.Y.: Brookhaven National Laboratory, Report no. BNL 50856. Prepared for the Assistant Secretary for Policy and Evaluation and the Assistant Administrator of the Energy Information Agency, U.S. Department of Energy by the Economic Analysis Division, Department of Energy and Environment.

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BROOKHAVEN ENERGY SYSTEM OPTIMIZATION MODEL (BESOM) (78-378)

Overview of Model

BESOM is a linear programming model of the energy sector of the economy that minimizes an objective function subject to constraints. The functions that can be minimized are total system cost, oil imports, capital requirements, environmental effects, or natural resource use, of producing a given set of energy services. A multiple criteria function can be optimized with the use of trade-off curves. The most commonly used objective function is minimized total system costs, subject to total energy demand, resource, pollution, and plant constraints.

Uses

BESOM, referred to as a process model by Brookhaven National Lab (BNL), is no longer used. Earlier work using BESOM included studies on electrification, technology assessment, interfuel substitution, oil stock piling, and a nuclear moratorium. (For references on these studies see Groncki and Marcuse 1979.)

Input

Input includes supply and demand efficiencies; conversion, extraction, and fuel costs; environmental impact factors; resource availabilities; basic energy demand; permitted market penetration; and load characteristics of all electric service demands.

Output

Output includes quantities of intermediate energy products, resources, and fuel use; optimal capacity load factors for electrical generating plants; environmental effects of producing energy products; shadow prices of variables and constraints; cost reduction necessary to bring a nonproduced product into the solution; total optimal system cost; and values of alternative objectives.

Modeling Structure and Techniques

BESOM is a linear programming model. The most common objective function to be minimized is total system costs with respect to intermediate energy products Z_j or:

minimize C_j Z_j subject to:

$$\begin{bmatrix} E_{uj} \\ D_{vj} \\ F_{wj} \\ G_{yj} \end{bmatrix} \begin{bmatrix} Z_j \\ \\ \\ \\ \end{bmatrix} = \begin{bmatrix} B_u \\ B_v \\ B_w \\ B_y \end{bmatrix}$$

where:

Z_j = vector of j intermediate energy products

C_j = the cost vector for the j energy products, Z_j

E_{uj}, D_{vj}, F_{wj}, G_{yj} = matrices representing the reference energy system. These matrices translate the intermediate energy products Z_j into resource use, end-use service demands, pollution production, and energy plant use. (see Figure 13 for technical relations)

B_u = the constraint vector for u energy resources

B_v = the demand constraint from the I-O model for the v end-use energy demands

B_w = the constraint for the w pollutants associated with production of Z_j

B_y = the y plant constraints associated with production of Z_j

E_{uj} and D_{vj} can allow for technological change over time.

Relationship to Other Models

See overview of Brookhaven Models above and DESOM AND TESOM below.

Computer Requirements

BESOM is compatible with Control Data Corporation computers.

TRANSPORTATION COMPONENT

The end-use transportation demands include automobile miles traveled, as well as travel by the other modes (rail, air, and bus). For auto miles, the model translates miles traveled into a demand for

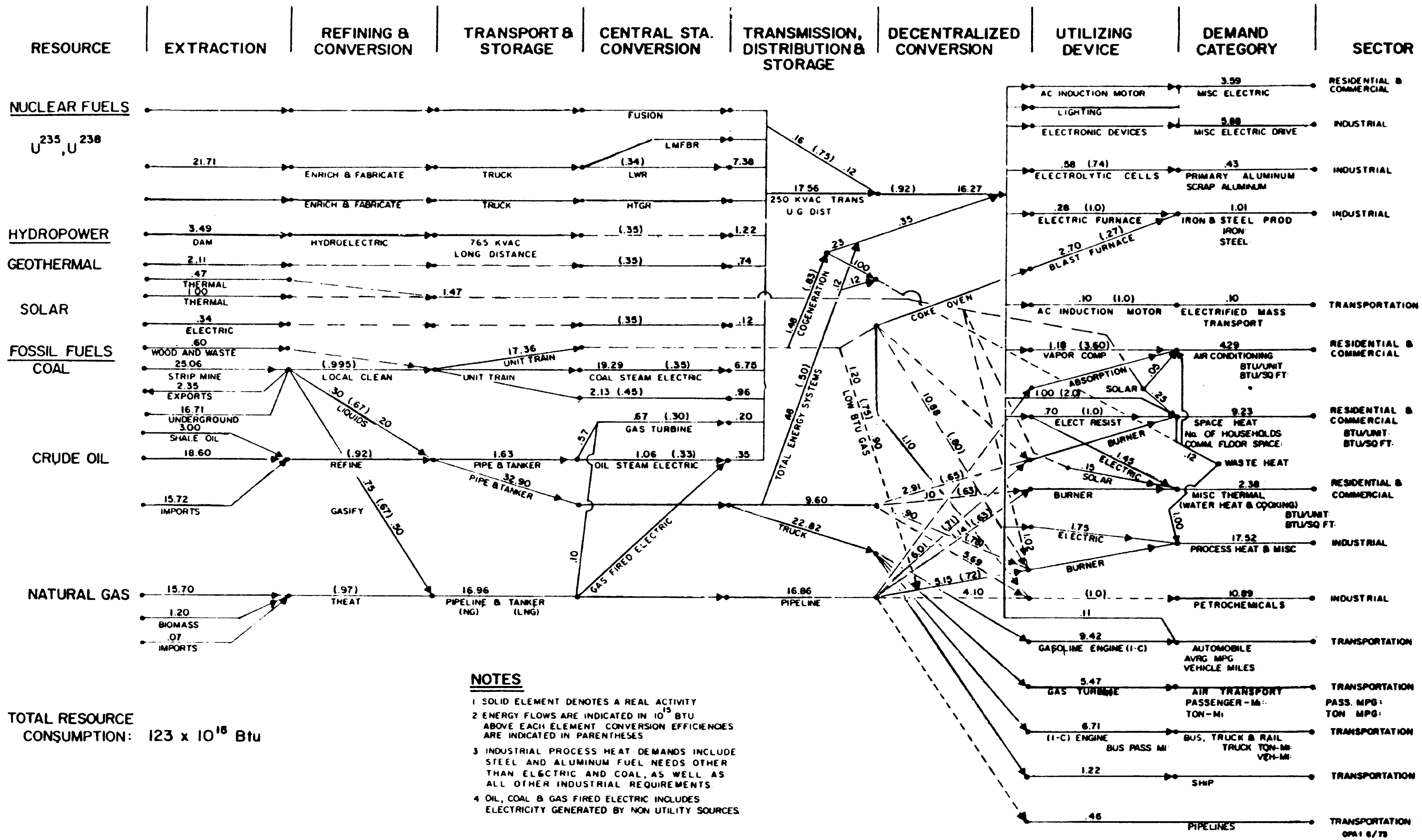

Figure 13
A Typical Reference Energy System, Year 2000, used in BESOM

Source: Kydes 1978

gasoline, and selects the share of gasoline that is produced from domestic crude oil, imported crude oil, oil shale, and coal liquification. A Reference Energy System depicts the flow of energy from the resource to the point of actual end-use. A typical system for a possible energy scenario in a future year is shown in Figure 13.

Structure

The modeling structure for this component is similar to that for the entire model discussed above. Total end-use vehicle miles traveled are predicted by the I-O Model and are a constraint in this linear programming model. The cost of producing these end-use services enters the cost function, and energy products used in their production are chosen through the optimization procedure. Thus the cost of end-use service production is minimized without exceeding resource availability, plant capacity, or pollution standards.

Input

Input necessary for the transport sector includes efficiencies for converting end-use demands (vehicle miles) into energy demand (gasoline), environmental impacts of producing gasoline, cost and efficiency of producing gasoline, and permitted market penetration for oil shale and coal liquification in gasoline production.

Output

Output includes gasoline consumption, products used for gasoline production, cost of crude oil, and cost of gasoline.

Assumptions

When BESOM is used alone, end-use energy service demands are fixed. Thus BESOM only captures the part of demand elasticity that is the result of substituting one energy form for another in producing end-use energy services. It does not capture changes in end-use energy services in response to price changes.

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Tessmer, R.C.; Hoffman, K.C.; Marcuse, W.; and Behling, D.J. 1975. Coupled energy system--economic models and strategic planning. Computer and Operations Research 2(3/4):213-224.

DYNAMIC ENERGY SYSTEM OPTIMIZATION MODEL (DESOM) (79-384)

Overview of Model

DESOM is a dynamic version of BESOM and a sequence of single-period linear programming models. It optimizes an objective function, usually the cost of producing a given set of end-use energy services, knowing supply availabilities, demand prices, and technology over the entire time frame under analysis. The model is dynamic because the n-time periods of the model are linked together by capacity transfer and resource availability constraints. The equations linking the time periods ensure that (1) cumulative resource use equals total resource consumption; (2) capacity and resource growth limit usage in any year to some proportion of previous usage; (3) in order to limit end-use device retirement, fuel inputs to end-use devices must not be less than some fraction of the preceding period; and (4) enriched uranium may be stockpiled.

Since the model has been used to perform an electric utility analysis for the Electric Power Research Institute, it includes a more detailed representation of electricity production than BESOM. Among the changes was the extension of the electrical sector to include load curves by season and by time of day.

Computer Requirements

DESOM is readily transferable to any CDC, IBM, or Univac computer that supports the PDS/Magen software package.

Transportation Component

The transportation component for this model is similar to that for BESOM, discussed earlier. The modeling structure for this component is also similar to that for BESOM, with the changes for DESOM as mentioned above.

Reference

Cherniavsky, E.A.; Juang, L.L.; and Abilock, H. 1979. Dynamic Energy System Optimization Model. Prepared for Electric Power Research Institute by Brookhaven National Laboratory. EA1079 research project 442-1.

Tessmer, R.C.; Hoffman, K.C.; Marcuse, W.; and Behling, D.J. 1975. Coupled energy system--economic models and strategic planning. Computer and Operations Research 2(3/4):213-224.

MARKET ALLOCATION MODEL (MARKAL) (78-398)

Overview of Model

MARKAL is the result of a cooperative effort by the International Energy Agency, Brookhaven National Laboratory, and Kernforschungsanlage (KFA, translated Nuclear Research Laboratory) in Julich, Germany. It is a single-country demand-driven, time-phased, linear programming model and is a second generation of the Dynamic Energy System Optimization Model (DESOM) (79-384). It has demand-side flexibility and interfuel substitution potential. Supply availabilities, demand, and technologies are assumed known over the entire time period as in DESOM, but the remaining technological characterizations (except for cost) allow for uncertainty, as in TESOM (below). The supply-side flexibility and process detail were adopted from a KFA model.

Uses

MARKAL has been used for technological assessment, conservation analysis, examining capital requirements, and investigation of conservation efforts, using security, cost, and "social concerns" as optimizing criteria.

Reference

Kydes, A. 1978. The Brookhaven Energy System Optimization Model. Its variants and uses. Upton, New York: Brookhaven National Laboratory.

TIME-STEPPED ENERGY SYSTEM OPTIMIZATION MODEL (TESOM) (79-383)

Overview of Model

TESOM is a time-stepped version of BESOM. It reflects uncertainty in the energy planning process since it assumes imperfect foresight with respect to future supplies, demands, prices, and available technologies.

Optimal levels of decision variables are determined from optimal levels in previous periods, along with assumptions on retirement rates, average lifespans, age-related functions (such as declining efficiencies, plant factors, and increasing operating and maintenance costs), costs of stock in place, and current economic conditions and the state of technology. Current work on the model includes several controlled approaches to market penetration.

Uses

TESOM is the engineering process model, or linear programming model, that has been used at Brookhaven National Laboratory since 1978, replacing the earlier versions (BESOM and DESOM). For a more specific discussion of uses see the Overview of Models section of the Brookhaven National Laboratory Modeling System above.

Transportation Component

The transportation component for this model is similar to that for BESOM, discussed earlier. The modeling structure for this component is also similar to that for BESOM discussed earlier with the changes for TESOM discussed in the overview above.

The major end-use energy service demands for transportation are represented by three basic sectors: (1) auto transport measured in vehicle miles; (2) air transport which is an aggregate of passenger miles and ton miles; and (3) bus, truck, and rail which is an aggregate of all their services. For these end-use energy service demands: the cost of their production is included in the objective function total system cost; the technical constraints are embodied in the constraint matrices; and the possible fuels used for their production are liquid fuels from the resources: crude oil, shale oil, crude oil imports, or coal.

Reference

Groncki, P.J.; and Marcuse, W. 1979. Brookhaven integrated energy/economy modeling system and its use in conservation policy analysis, Preliminary copy. Upton, New York: Brookhaven National Laboratory report no. BNL 51056.

Kydes, A.S. 1978. Brookhaven Energy System Optimization Model--its variants and uses. Upton, New York: Brookhaven National Laboratory report no. BNL 50873.

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LONG-TERM INTERINDUSTRY TRANSACTIONS MODEL (LITM) (77-242)

Overview of Model

LITM is an econometric simulation model of the U.S. economy by Dale W. Jorgenson Associates and consists of four-sector macroeconomic model and a ten-sector variable coefficient interindustry model (see Figure 14).

Uses

The model, useful for long-term economic analysis, projects macroactivity, a matrix of input-output coefficients, and the level of activity and prices in each of the ten industrial sectors. A typical projection would be from 1975 to 2000. For the model use in conjunction with the BNL models see the Overview of Models of the Brookhaven Modeling System above.

Input

Input to the interindustry model includes producer mark-ups, the price of imports, and productivity in each sector. Input to the interindustry model from the macromodel includes total real personal consumption of goods and services for the U.S., private domestic investment, government expenditures (on investment, consumption, and labor), prices for capital and labor, and price deflators for consumption and investment. Input to the macromodel includes an aggregate productivity index, rate of depreciation, aggregation variables relating capital stock to investment and to capital services, aggregation variables relating the price of investment to the price of capital stock and to asset price, unemployment, time available to the household, population, taxes, and price deflators for the various components of aggregate demand going to government or to exports.

Output

Output from the interindustry model includes input-output coefficients; consumption, government spending, and investment demand

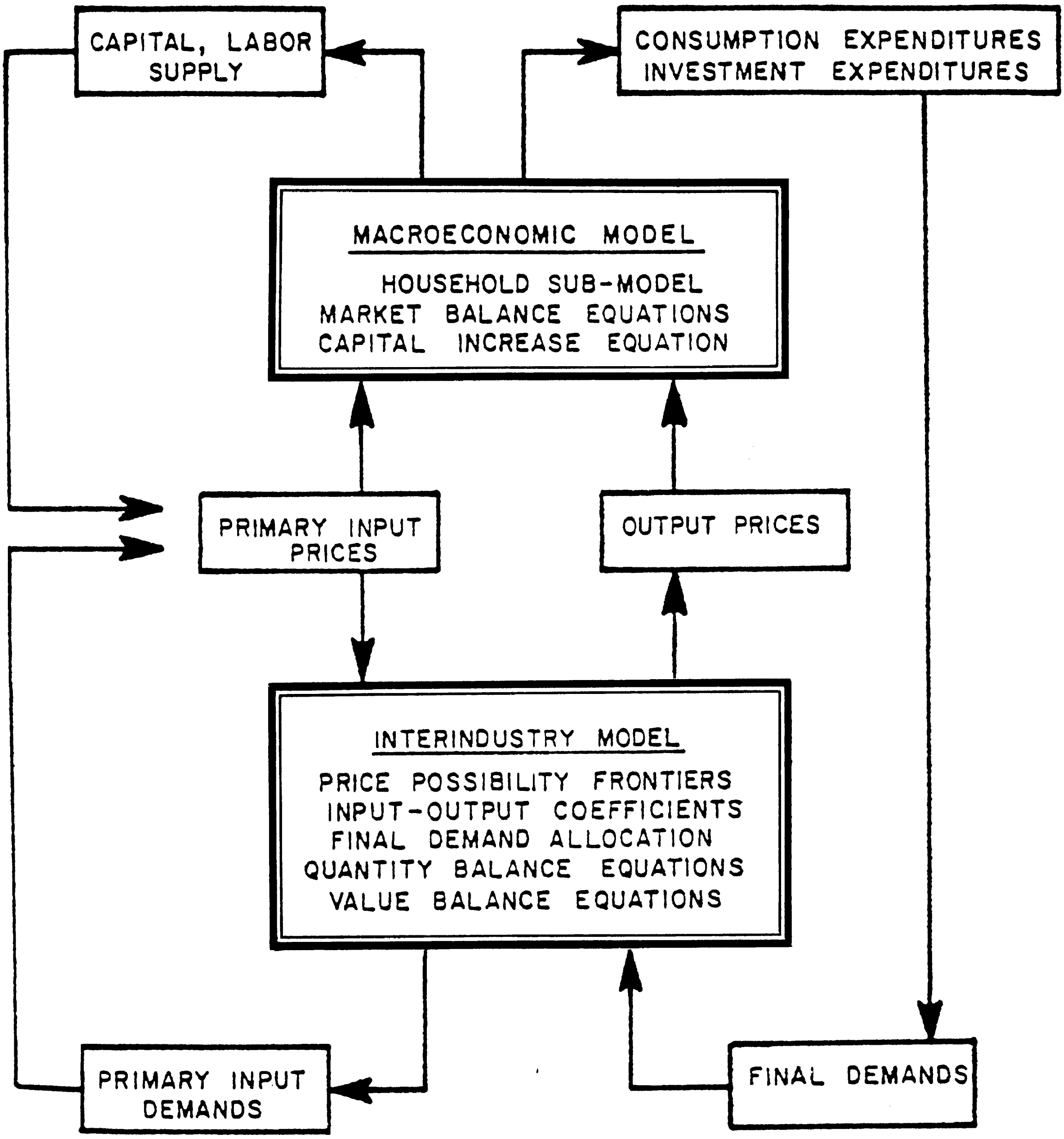

Figure 14
Economic Flows in LITM

Source: Groncki and Marcuse 1979

for goods in each of the ten sectors; total demand for capital and labor; output price for each sector; price of good i paid by sector j; price of energy input and intermediate materials to each sector; price of each good to consumers, government and investors; demand for imports; real output of each sector; and total real demand for each output.

Output from the macromodel includes consumption, investment, capital stock, capital services, supply of labor, purchases of labor by production sector, leisure, rate of return on capital, and price deflators for consumption, investment, labor, savings, and wealth.

Modeling Structure and Techniques

The interindustry model is a variable coefficient input-output model of the whole economy that uses the exogenous prices of capital, labor, and imports to predict prices in the following sectors:

1) agriculture, nonfuel mining, and construction;
2) manufacturing, excluding petroleum refining;
3) transportation;
4) communication, trade, and services;
5) coal mining;
6) crude petroleum and natural gas;
7) petroleum refining;
8) electric utilities;
9) gas utilities; and
10) natural gas extraction.

Prices and input-output coefficients are calculated by the simultaneous solution of a system of price possibility frontiers. The coefficients along with disaggregated final demand from the macromodel comprise the input-output model that is solved for total products in the ten sectors.

The macromodel predicts aggregate consumption, aggregate investment, and the prices of capital and labor, taking government spending and net exports as exogenous. The model includes estimated equations for investment supply, labor demand, consumption demand, leisure demand, a production-possibility frontier, and imputed services for consumer durables. The remainder of the model consists of capital equations that show accumulation and capital services, market balance equations, and linkage equations.

Relationship to Other Models

The model has been used in conjunction with the Brookhaven I-O Model and TESOM. For the relationship to the Brookhaven National

Laboratory Modeling System see the Overview of Model section of that system. DGEM, described below, is a second-generation LITM.

Computer Requirements

LITM is proprietary to Dale W. Jorgenson Associates.

TRANSPORTATION COMPONENT

Aggregate transportation is one of the ten producing sectors in the interindustry model.

Structure

Transportation, incorporated into the interindustry model, is represented as three price possibility frontiers: one for the price of transportation, one for the aggregate price of energy inputs for transportation, and one for the aggregate price of material inputs for transportation. These three price possibility frontiers, together with three frontiers for each of the other nine sectors (all estimated econometrically), are solved simultaneously for prices.

Input

Input includes productivity and producer mark-up in the transportation sector. The aggregate demand for transportation is input from the macromodel.

Output

Transportation output includes input-output coefficients relating transportation to the other producing sectors, price of transportation, price of materials and energy used in transportation, and intermediate and final demand for transportation.

References

Groncki, P.J. and Marcuse, W. 1979. Brookhaven integrated energy/economy modeling system and its use in conservation policy analysis. Preliminary copy. Upton, New York: Brookhaven National Laboratory report no. BNL 51056.

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DYNAMIC GENERALIZED EQUILIBRIUM MODEL (DGEM) (78-243)

Overview of Model

In DGEM, a second-generation LITM under development by Data Resources, Inc., the interindustry model is being expanded from ten to thirty-six sectors.

Transportation Component

The transportation component of the interindustry model has been divided into three production sectors: (1) motor vehicles; (2) transportation equipment and ordinance, except motor vehicles; and (3) transportation. The model, when completed, should predict aggregate end-use demand and the price of output and input into these three sectors, as well as for the other 33 sectors. Other input and output are similar to that of LITM.

Uses

This model had not been completed as of February 1980, but initial work on the model was estimated using 1974 data. Jack Faucett Associates, Inc., has a contract for data preparation. It is expected that it will be used by the General Services Administration, one of its sponsors, and that it will replace LITM at Brookhaven National Laboratory.

Reference

Hudson, E.A.; Jorgenson, D.W.; and O'Connor, D.W. 1978. The Dynamic Generalized Equilibrium Model linear logarithmic specification. Cambridge, Massachusetts: Data Resources, Inc. Report to Applied Economics Division, Federal Preparedness Agency, General Services Administration.

CENTER FOR ADVANCED COMPUTATION/BROOKHAVEN ENERGY INPUT-OUTPUT MODEL (78-361)

Overview of Model

The I-0 model is a 110 sector input-output model originally developed by the Center for Advanced Computation at the University of Illinois and modified by Brookhaven National Laboratory. Given total final demands from the macro interindustry model, the I-0 model provides a disaggregate accounting framework for estimating total energy, capital, and material requirements to produce total energy demands for the 110 sectors. These total energy demands are used as constraints in the linear programming model.

Uses

This model has been used in conjunction with the linear programming model to investigate interfuel substitution and the effects of oil stockpiling on a nuclear moratorium. It has been used in conjunction with the linear programming models and LITM to investigate energy-economy interactions, the effect of conservation, and the effect of solar technology.

Input

Final demands for each of the 10 sectors in LITM are disaggregated into 110 sectors and are fed into the I-0 model (i.e., Y_S, Y_P, Y_I, below) The input-output coefficients for the energy sector (i.e., A_{SS}, A_{SP}, below are fed in from TESOM.

Output

Total demands from all 110 sectors (i.e., X_S, X_P, X_I, below) are output.

Modeling Structure and Techniques

Fraser (1978, p. 8,9) reports the equations of the I-0 model can be written as:

$$A_{SS} X_S + A_{SP} X_P + Y_S = X_S$$

$$A_{PS} X_S + A_{PI} X_I + Y_P = X_P$$

$$A_{IS} X_S + A_{II} X_I + Y_I = X_I$$

where the matrix coefficients are:

$A_{SS}(12x12)$ = input-output coefficients describing sales of the output of one energy/supply conversion sector to another energy conversion sector and conversion losses incurred in producing or distributing energy (e.g., sale of crude oil to refineries)

$A_{SP}(12x8)$ = input-output coefficients describing how distributed energy products are converted to end-use forms (e.g., refined oil products required to produce motive power)

A_{SI} = 0 implying that energy supplies are not used by nonenergy producing sectors; energy products are used by the nonenergy-producing sectors.

$A_{PS}(8x12)$ = input-output coefficients describing how energy products--final energy forms--are used by the energy-supplying industries. Included here would be electricity used for lighting a refinery.

A_{PP} = 0 implying that energy products are not used to produce energy products

$A_{PI}(8x90)$ = input-output coefficients describing how energy products--final energy forms--are used by nonenergy-producing sectors. This submatrix describes the ways end-use energy forms are used in the nonenergy-producing sectors. Examples are blast furnace heating or space heating.

$A_{IS}(90x12)$ = input-output coefficients describing the uses of nonenergy materials and services by the energy industry such as pipes or pumps

A_{IP} = 0 implying energy product sectors equipment require no material or service inputs. This is because they are pseudosectors and not real producing sectors.

$A_{II}(90x90)$ = input-output coefficients describing how nonenergy products are used in the nonenergy-producing sector

$X_S(12x1)$ = production of basic energy

$X_P(8x1)$ = production of energy products or services such as space heat

$X_I(90x1)$ = production of nonenergy products

$Y_S(12x1)$ = end-use demands for basic energy resources

$Y_P(8x1)$ = end-use demands for energy products or services

$Y_I(90x1)$ = end-use demands for nonenergy products

A_{SS} and A_{SP} in the most recent version come from TESOM (79-383). Y_S, and Y_I are disaggregated from LITM (77-242). Output from the model are X_S, X_P, and X_I. X_S and X_P are used as constraints in TESOM.

Relationship to Other Models

The model when used interactively provides an interface between TESOM and LITM. Y_S, Y_P, and Y_I are disaggregated from LITM, and A_{SS} and A_{SP} are derived from TESOM. The current 110 sector version is an expansion of the original 101 sector CAC/Brookhaven I-O model.

Computer Requirements

The model is CDC compatible.

TRANSPORTATION COMPONENT

Of the 110 sectors of the model, 11 relate to transportation, specifically. These sectors include motor vehicles and equipment; aircraft and parts; other transportation equipment; railroads and related services; local, urban, and interurban highway passenger transport; motor freight transportation and warehousing; water transportation; air transportation; pipeline transportation; transportation services; and automobile transportation and services.

The basic structure of the model can be explained more intuitively in terms of one of the transportation sectors. Given end-use demand for motor vehicles and equipment, the model calculates all the inputs required to produce this final demand contained in the Y_I vector plus the quantity of motor vehicles and equipment required to produce other goods.

Input

Final demand for the transportation sectors is disaggregated from end-use demand for transportation in LITM and used as an input to the I-O model.

Output

Transportation output includes total demands for the above 11 sectors and inputs necessary for their production. Total demand for motive power and for energy inputs are used as a constraint in TESOM.

Assumptions

The disaggregation of demand from the ten industries in LITM into 110 sectors in the I-O model is done exogenously for all but the energy sector. The disaggregation of the energy sector is calibrated with the linear programming model. The I-O coefficients are constant except for technical change for all sectors but the energy sector. Thus, the model is designed to capture substitution effects only in the energy sectors.

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Lukachinski, J.; Groncki, P.J.; Tessmer, R.G., Jr.; Goettle, R.D., IV; and Hudson, E.A. 1979. An integrated methodology for assessing energy-economy interactions. Upton, New York: Brookhaven National Laboratory report no. BNL 26452.

Summary and Comparison of Energy Model Transportation Sectors

The models examined in this paper can be divided into two categories. The first category contains midrange econometric forecasting models, including the MEFS and TECNET modeling systems. The second category contains long-range, noneconometric scenario-comparison models, including the SRI-Gulf type models and the Brookhaven National Laboratory (BNL) models. The EEA Highway Fuel Consumption Model is an accounting model and is not included in either of these two general categories.

The econometric models estimate behavioral relationships through the application of economic and statistical theory to historical data. These models are of special interest in analyzing policies that are intended to alter economic behavior in the light-duty vehicle sector, as they are generally designed for this purpose. Examples of such policies are gasoline taxes, fuel economy standards, and excise taxes and rebates. The light-duty vehicle sectors are modeled in considerable detail, compared to the second category of models, and have "stand-alone" capabilities. The TECNET model is broader than the other econometric models in that it considers the environmental aspects of the motor vehicle system.

The econometric models vary in their theoretical approaches to both demand and supply sides of the vehicle market. Three of the models, Sweeney, Faucett, and TECNET, estimate new-vehicle demand with variations of the stock-adjustment model. Faucett also estimates size-class market shares of new-vehicle demand. The ORNL Highway Gasoline Demand Model (HGDM) is based on the hypothesis that new cars are distinctly different from used cars and are not aggregatable through a stock-adjustment process. Furthermore, HGDM is also based on the hypothesis that the different vehicle classes are generally goods with limited substitutability. These two hypotheses are reflected by the estimation of separate demand equations for each vehicle class. None of the models estimate the foreign and domestic market shares. Different vehicle technologies (leaded, unleaded, and diesel) can be simulated with Sweeney, TECNET, and HGDM. TECNET (proposed) and HGDM can also simulate the impact of other vehicle technologies (e.g., electric, turbine, and Sterling). The Faucett and Sweeney models incorporate a supply side to simulate industry responses affecting vehicle fuel economies. Approaches to modeling scrappage, vehicle miles traveled, and vehicle fuel consumption also vary across the models.

In contrast to those models in the first category, the noneconometric models do not emphasize the modeling of consumer and industry behavior. Rather, economic behavioral relationships (in the form of supply and demand elasticities) generally must be introduced from outside the models. These noneconometric models focus more on the sectoral interactions of a large range of economic activities--such things as interfuel substitution, introduction of new technologies, and "energy-economy" interactions--of which transportation activities are a few of many economic sectors.

The SRI-Gulf-type model attempts to simulate the theoretical operation of a market economy. Decentralized decision-making is incorporated by connecting economic and technical processes with "markets" and other processes. Assumptions are made about the extent and speed of adjustment these markets are subject to in attaining equilibrium.

The BNL model system consists of an interconnected macroeconometric model, input-output model, and linear programming (LP) model. The LP model is central to the system, and optimizes a single objective function, for example minimizing total system cost. Since it is an engineering process or activity analysis model, the LP model imposes a number of constraints on the economics that are unnecessary in other types of models, one of which is constant returns to scale.

The light-duty vehicle sectors of the noneconometric models are not as comprehensive as those of econometric models, at present generally going little beyond fuel prices, quantities, and travel by transit mode. However, for specific applications a sector can be developed in greater detail. Generally, the models can be used to analyze such traditional macroeconomic policy variables as taxes, subsidies, price controls or supports, and supply restrictions. In addition, the BNL models can be used to analyze the impacts of macroeconomic and environmental policies and fuel economy standards. Thus many of the same policies can be analyzed by both general types of models, but the levels of detail and forms of input and output are different.

The tables that follow present a more detailed summary comparison of the energy model transportation sectors. The models can be divided into four groups that represent different types of modeling systems: the MEFS models, the TECNET model, the SRI-Gulf model and its derivatives, and the BNL modeling system. Table 5 presents an intergroup comparison. Tables 6, 7, 8, and 9 present intragroup comparisons with TECNET grouped with MEFS. Table 6 compares TECNET and the various MEFS models, excluding the EEA Highway Fuel Consumption Model (an accounting model) and the minor fuels models of MEFS. Table 7 summarizes the status, input, output, and policy uses of the EEA Highway Fuel Consumption Model. Table 8 compares the SRI-Gulf model and its descendants. Table 9 compares the various versions of the LP and macroeconometric models, and maps the linkages between the macro, LP, and input-output models that make up the BNL modeling system.

TABLE 5

TRANSPORTATION COMPONENT CHARACTERISTICS

TYPES	FORECASTING MODELS		SCENARIO COMPARISON MODELS	
	MEFS	TECNET	SRI/GULF AND DERIVATIVES	BROOKHAVEN MODELS
Forecast Horizon	Mid-range (6-19 yrs)	Mid-range (Revised) Long-range (Original)	Long-range (to 2020)	Long-range (to 2025)
Policies user can simulate (varies somewhat for each model within a model class)	• Gasoline taxes • Fuel economy standards • Vehicle taxes/ rebates	• Gasoline taxes • Fuel economy standards • Vehicle taxes/ rebates • Emissions regulations • Gasoline shortages	• Price controls or supports • Quantity controls • Tax credits and subsidies for technologies of fuels and transportation (e.g., shale oil, electric vehicles) • Policies that alter production costs	Optimize user's objective function (e.g., minimize total systems cost or environmental impacts) given: • Fuel supply restrictions • Fuel stockpiling • Feedback effects of energy and economic policies on each other • Tax credits and subsidies for technologies of fuels and transportation • Fuel economy standards for autos • End-use energy service demands
Policy impact variables	• Fuel consumption • Vehicle miles traveled (VMT) • New-vehicle sales • Vehicle fleet characteristics • Fuel efficiency • Vehicle prices	Same as MEFS, but also: • Personal travel demand • Goods transport • Vehicle emissions • Modal split for VMT	• Vehicle miles traveled • Fuel prices and quantities • Interfuel substitution • Market penetration of new-vehicle or fuel technologies • Modal split for VMT	• Vehicle miles traveled • Total energy cost • Environmental costs • Fuel prices and quantities • Interfuel substitution • Market penetration of new-vehicle or fuel technologies • Shadow prices of fixed factors • Balance of trade

TABLE 5

TRANSPORTATION COMPONENT CHARACTERISTICS (Continued)

TYPES	FORECASTING MODELS		SCENARIO COMPARISON MODELS	
	MEFS	TECNET	SRI/GULF AND DERIVATIVES	BROOKHAVEN MODELS
Technique	Econometric/ Equilibrium	Econometric	General equilibrium market (decentralized decisionmaking)	Linear Programming Input-Output, and Econometric
Economic aspects				
Level of detail	• Auto market by vehicle class • Auto industry monolithic	• Similar to MEFS	• VMT can be split by mode or type (urban vs rural) • Detail can be expanded for specific purposes	• VMT can be split by mode or type in LP model • In Econometric model aggregate transportation is one sector • In I-O model, transportation is represented by several sectors
Demand	• Behavioral relationships estimated	• Behavioral relationships estimated	• VMT demand schedules required	• VMT demand--exogenous schedule or estimated by linked macro-econometric growth model and I-O model • I-O energy coefficients estimated as functions of prices
Supply	• Auto sector behavioral relationships assumed • Fuel supply simulated by other MEFS models or perfectly elastic at user set price	• Auto sector behavioral relationships assumed • Fuel supply shortage can be simulated	• Needs resource supply curves and cost information for produced input • Temporal supply adjustment represented by constraints on market penetration of new technology	• Requires exogenous fixed supplies or stepwise supply schedules • Temporal supply adjustment represented by constraints on market penetration of new technology

TABLE 5

TRANSPORTATION COMPONENT CHARACTERISTICS (Continued)

TYPES	FORECASTING MODELS		SCENARIO COMPARISON MODELS	
	MEFS	TECNET	SRI/GULF AND DERIVATIVES	BROOKHAVEN MODELS
Input (varies by model within each class of models)	• Economic and demographic projections • Market shares--domestic vs imported • Vehicle technological costs • Vehicle fuel economies • Fuel prices • Existing fleet composition and fuel economies • Vehicle prices • Vehicle technology penetration factors • Policy variables	• Economic and demographic projections • Market shares--domestic vs imported, cars vs light trucks • Emissions factors • Vehicle fuel economy assumptions • Diesel market penetration assumptions • Fuel prices • Existing fleet composition and fuel economies • Policy variables	• VMT demand schedules • Costs of production • Resource supply curves • Initial market shares of fuels • Constraints on changes in fuels' market shares • Distances for goods transport • Networks • Initial market availability of new technologies • Maximum rate of penetration of new technologies	• Economic and demographic projections • Productivity in transportation sector • Producer mark-ups in transportation • Exports • Import prices • Fiscal policy variables • Market penetration characteristics of new technologies
Output (varies by model within each class of models)	• Fuel consumption: leaded, unleaded, diesel • New-vehicle sales • VMT by mode • Vehicle fleet characteristics • Vehicle prices	• Fuel consumption: leaded, unleaded, diesel • New-vehicle sales • VMT, PMT by mode • Vehicle fleet characteristics • Vehicle emissions by mode • Goods transport	• Equilibrium prices and quantities of fuels and VMT • Equilibrium VMT modal split (inter-intra city, auto, light trucks, heavy trucks, buses)	• Prices and quantitites of fuels, other transportation sector inputs, and VMT--auto, air, ship, bus, truck, and rail

TABLE 6

COMPARISON OF MEFS TRANSPORTATION AND TECNET MODELS

	MEFS			
	PASSENGER CAR GASOLINE DEMAND MODEL (Sweeney)	AUTOMOBILE SECTOR FORECASTING MODEL (Jack Faucett Associates)	HIGHWAY GASOLINE DEMAND MODEL (ORNL)	REVISED TECNET (CONSAD/MITRE)
	STATUS			
	• Updated in 11/79 • Latest data used to estimate equations, 1977	• Updated in 1977 • Equations not reestimated. Latest data used in estimation, 1975	• Programmed • Latest data used in estimation, 1977	• Draft documentation available • Not programmed as of 7/80 • Latest data used in estimation, 1977
	BASIC THEORETICAL APPROACH			
Demand side	• Aggregate demand for automobile gasoline use derives from consumer desire for mobility as translated into VMT and consumer preferences over the capital stock of autos • New-car price is an explanatory variable in the new-car sales equation, assumed that price is primarily determined by cost and does not significantly depend on demand	• Similar to Sweeney	• Household production theory approach • Separates elements of household production technology from tastes	• Travel demand primarily determined by economic growth and cost, except if travel approaches saturation levels then time budgets are controlling • Person miles traveled (PMT) more closely approximates service demanded than does VMT and allows model to shift PMT among modes

TABLE 6

COMPARISON OF MEFS TRANSPORTATION AND TECNET MODELS (Continued)

	MEFS			
	PASSENGER CAR GASOLINE DEMAND MODEL (Sweeney)	AUTOMOBILE SECTOR FORECASTING MODEL (Jack Faucett Associates)	HIGHWAY GASOLINE DEMAND MODEL (ORNL)	REVISED TECNET (CONSAD/MITRE)
	BASIC THEORETICAL APPROACH (Continued)			
Supply side	• Auto supply side changes implicit in "technical efficiency" relationship between weight and fuel economy, and in price effect terms for costs of downsizing or reducing car weight • Fuel supply assumed perfectly elastic, dummy variable used for 1974 in estimations of VMT to represent gasoline shortage	• An algorithm minimizes auto cost to consumer • Projected fuel economy/ cost relationships provided • Gasoline supply assumed perfectly elastic at given price • Vehicle supply assumed perfectly elastic at algorithm determined prices	• New-vehicle supply assumed perfectly elastic • Used-vehicle supply estimated by state • Fuel supply perfectly elastic	• Vehicle supply assumed perfectly elastic, except as otherwise might be implied by Sweeney fuel economy relationships and limitations on the supply of vehicles with very high fuel economies (which would not be limited by Sweeney model) • Fuel supply perfectly elastic
	INPUT			
Policy variables	• Gasoline tax • Mean fuel economy standard (national)	• Gasoline price • Excise tax/rebate • Fuel economy standards/ penalties	• State gasoline prices • Fuel economy	• Fuel price and availability • Fuel economy and emissions standards • Mass transit fares and availability • Mass transit speeds • Intercity transport fares • Highway and air travel speeds

TABLE 6

COMPARISON OF MEFS TRANSPORTATION AND TECNET MODELS (Continued)

	MEFS			
	PASSENGER CAR GASOLINE DEMAND MODEL (Sweeney)	AUTOMOBILE SECTOR FORECASTING MODEL (Jack Faucett Associates)	HIGHWAY GASOLINE DEMAND MODEL (ORNL)	REVISED TECNET (CONSAD/MITRE)
INPUT (Continued)				
Other exogenous variables	• Population, disposable income, unemployment, CPI, CPI for autos, avg. weekly hours, avg. hourly wage, avg. speed, fuel prices, fuel economy technology, fuel economy of imports, import fraction of sales, fraction using unleaded gasoline and diesel	• Population, disposable income, unemployment rate, technology forecasts, existing fleet composition, base fuel economies, and base auto prices • Constant proportions of each size class are assumed for each of 5 "manufacturers", incorporates foreign/domestic shares	• State level: population, no. of households, SMSA pop., pop. age <18, pop. age 18-44, disposable income, unemployment, farm earnings, cost of living index, rural VMT fractions, correction factors for fuel efficiencies • National: auto finance rate, maintenance cost index • Vehicle class: prices, % using vehicle technologies (unleaded and leaded gas, diesel, electric, etc.), city and highway fuel economies (EPA)	• Economic and demographic data provided by INFORUM • Other exogenous variables needed for "Sweeney" parts of the model • Car vs. truck shares of sales
OUTPUT				
New vehicle demand	• Stock adjustment model • Demand per capita estimated as a function of unemployment, gasoline and auto prices, income and effective stock	• Stock adjustment model • Desired stock estimated from cross-section data as function of income • Unit demand estimated as a function of desired and existing stocks, index of purchase price, and fuel costs	• New vehicles are distinctly different from used vehicles • Demand estimated for cars (5 classes), light trucks and vans • State-level demands are a function of vehicle and fuel prices, income, pop., age, spatial distribution and size, unemployment	• Same as Sweeney, except multiplied by 1.17 to include light trucks
Fleet size	• Measured in new car equivalents • Depends on vehicle survival rates	• Measured in no. of vehicles • Depends on scrappage rates	• Same as Faucett, but on state, regional, and national levels	• Same as Sweeney

TABLE 6

COMPARISON OF MEFS TRANSPORTATION AND TECNET MODELS (Continued)

	MEFS			
	PASSENGER CAR GASOLINE DEMAND MODEL (Sweeney)	AUTOMOBILE SECTOR FORECASTING MODEL (Jack Faucett Associates)	HIGHWAY GASOLINE DEMAND MODEL (ORNL)	REVISED TECNET (CONSAD/MITRE)
OUTPUT (Continued)				
Scrappage	• Age 0-15 a function of age and cumulative VMT • Age >15 a geometric decline assumed	• Age <9 constants assumed • Age $\geq$9 estimated as function of unemployment and index of purchase prices	• Estimated as a function of vehicle age and used-vehicle price relative to repair costs • State migration is considered for vehicles age 1-4 years	• Same as Sweeney
Vehicle price	• Exogenous, an index of CPI for new cars relative to overall CPI	• Base price exogenous, increments determined by cost minimization algorithm	• New-vehicle price exogenous • Used-vehicle price a function of new-vehicle price	• Exogenous
Vehicle-class market shares	• Not an explicit output • Implicit in calculation of model year fuel economy	• 3 auto size-class shares estimated as a function of prices by class, and lagged market shares • classes chosen based on vehicle weights	• New-vehicle demand estimated for 6 classes • Classes chosen using cluster analysis	• Exogenous, except implicit Sweeney approach to fuel economy used • Car-truck split exogenous
Fuel economy	• Estimated as a function of gas price, technical efficiency, also influenced by standards	• Base fuel economies exogenous, increments determined by cost minimization algorithm • CAFE calculated for 5 "manufacturers"	• Exogenous by vehicle class and technology • State, regional, and national fuel efficiencies are estimated	• 3 alternatives: same as Sweeney, based on the standards, or exogenous

TABLE 6

COMPARISON OF MEFS TRANSPORTATION AND TECNET MODELS (Continued)

	MEFS			
	PASSENGER CAR GASOLINE DEMAND MODEL (Sweeney)	AUTOMOBILE SECTOR FORECASTING MODEL (Jack Faucett Associates)	HIGHWAY GASOLINE DEMAND MODEL (ORNL)	REVISED TECNET (CONSAD/MITRE)
	OUTPUT (Continued)			
VMT demand	• VMT (per capita) estimated as a function of: disposable income, gasoline price and availability, number of cars, population, and available time • VMT is disaggretated by fuel type (unleaded and leaded gasoline, diesel fuel)	• VMT (per household) estimated as a function of: disposable income, gasoline price, number of cars, and population	• VMT calculated from demand for fuel and fuel efficiency for state, regional and national levels by vehicle class and technology	• Derived from demand for PMT • Estimated separately for categories divided according to work related vs. personal, intercity vs. local • Modal splits are estimated for these categories • VMT does <u>not</u> depend on vehicle stock
Fuel demand	• Calculated as the ratio of VMT to average fuel economy	• Calculated from estimated VMT's and fuel economy ratings by vintage and class	• Estimated on state level as a function of vehicle ownership by class and gasoline price, income, pop. spatial distribution, average fuel economy, maintenance costs, and state intercept terms	• Calculated using VMT and fuel economy • 3 alternative procedures
Fuel demand shares	• Leaded and unleaded gasoline, and diesel	• Not considered	• Leaded and unleaded gasoline, diesel, 2 other user-specified fuels • Electricity consumption not considered	• Leaded and unleaded gasoline, diesel, 2 other alternative fuels • Assumes for each model year either all unleaded or all leaded for gasoline
	COMMENTS			
	• Being modified to include light-duty trucks	• Fuel economy technology cost relationships have been updated	• Recently modified for analyzing the impacts of electric vehicle market penetration	• Also provides estimates of vehicle emissions and goods transport

TABLE 7

EEA HIGHWAY FUEL CONSUMPTION MODEL SUMMARY

Status	Expanded in 5/80 to include medium- and heavy-duty trucks
Input	• Annual new-vehicle registrations • Scrappage rate of new vehicles • Annual VMT per vintage • New-vehicle average fuel economy for EPA tests • On-the-road miles per gallon discount factor accounting for in-use driving conditions to reduce actual fuel economy below EPA test values • New-vehicle diesel penetration estimates
Output	• Average new-vehicle fuel economy, both on-the-road and EPA • Average fleet fuel economy, on-the-road and EPA • New-vehicle registrations for spark ignition and diesel engines • Fleet vehicle registrations for spark ignition and diesel engines • Total vehicle miles of travel disaggregated by vehicle type • Fuel consumption by diesel fuel, leaded gasoline, and unleaded gasoline
Method-ology	An accounting model without behavioral relationships
Possible policy uses	• Effects of changes and standards on fuel efficiencies • Effect of introduction of different fuel or engine types

TABLE 8

COMPARISON OF SRI/GULF MODELS

	SRI/GULF	EPM/LLL	GEMS/DFI	LEAP/DOE
Origin and characteristics (differences from 1st version)	• Earliest version • Regional: 8 demand regions, 12 supply regions • Networks fixed • Free market model • Provisions for pricing emissions and generating volumes and social prices of emissions (not yet used)	• Lawrence Livermore Lab revised • Regional: 9 demand regions and 12 supply regions • New computer language facilitates building networks • Networks built/ expanded for each model application • New capability allows modeling of nonequilibrium situations • Can represent gov't. regulation by changes in costs or technology, or by price and quantity controls • Refined microeconomics	• Decision Focus (DFI) revised • Nonregional • New software to facilitate ease of network changes • Networks are built to fit each model application • Allows feedback between the economy and energy system • Refinements in microeconomics	• Version of GEMS sold to DOE by DFI • DOE has made internal changes • Can maintain several levels of geographic disaggregation • Calibrated to MEFS • New software to to facilitate the incorporation of data changes and the analysis of model outputs
Recent transportation uses	• Simulation of gov't. policy impacts on synthetic fuels market and effect on Gulf profits	• Electric vehicle market analysis • Impact of federal fuel economy standards • Gasoline price increase impacts • Alternative fuels and engine systems	• Electric vehicle market analysis	• Electric vehicle market analysis (assumed to supply only urban VMT)

TABLE 8

COMPARISON OF SRI/GULF MODELS (Continued)

	SRI/GULF	EPM/LLL	GEMS/DFI	LEAP/DOE
Input	• SRI-Gulf internal data base, includes processing of subjective information • End-use own-price elasticity of demand for auto VMT is assumed to be -0.38 • End-use demands are fixed	• Revisions of SRI-Gulf data base • VMT demand derived from Wharton EFA auto model • End-use demand can be made sensitive to prices	• Revision of SRI-Gulf data base • End-use demand can be made sensitive to prices	• Same data requirements as other versions, but data are provided from MEFS, DOT, ORNL, in-house and other sources • LEAP is calibrated with MEFS through 1995 • End-use service demands are a function of price, GNP growth rate, etc. • End-use demands are sensitive to price
Output	• VMT--quantity and price • Prices and market shares of fuels • Emissions--quantity and price (not yet used)	• VMT--quantity and price • Prices and market shares of fuels--gasoline, diesel, methanol, electricity	• VMT--quantity and price • Urban vs. rural VMT split • Electric vehicle VMT • Prices and market shares of fuels	• VMT--quantity and price • Intercity vs. intracity VMT split • Light truck, heavy truck, and bus shares of VMT • Prices and market share of fuels used in transportation

TABLE 9

COMPARISON OF BROOKHAVEN MODELS

	LINEAR PROGRAMING MODELS			
	BESOM	DESOM	MARKAL	TESOM
Origin and characteristics	• Earliest version • Minimizes total system cost subject to supply, demand capital, and pollution constraints • Has been superseded	• 1st dynamic version • Sequence of BESOMs tied together • Perfect knowledge of past and future for optimization • Treats plant expansion, exhaustible resources, capital requirments explicitly • Improved software • More detailed representation of electric utilities	• Improved DESOM • More flexible and detailed supply side • Improves demand side behavior of market penetration of new technologies	• Improved DESOM • Reflects uncertainty by optimizing using only knowledge of past and present, unlike previous versions uses "current" assumptions about supplies • A vintage capital stock approach • Improved market penetration algorithm • Step-wise resources supply rather than resource availability • Version currently used

	LINEAR PROGRAMING MODELS
Assumptions	• Technology characterizations • Environmental emission relations • Energy supply relations
Input	If only connected to I-0 model: • Sectoral energy demands, from I-0 model • Total energy outputs for demand constraints, from I-0 model If connected to macromodel and I-0 model: • Energy end-use demands adjusted to reflect macromodel outputs mapped through "reduced form" of the I-0 model, and initial energy product coefficients from the I-0 model
Output	To I-0 model and Macromodel: • Energy flows, aggregate energy demands • Oil and gas imports--prices and quantities • New technology

TABLE 9

COMPARISON OF BROOKHAVEN MODELS (Continued)

	MACROECONOMIC INTERINDUSTRY MODELS		INPUT-OUPUT MODEL
	LITM	DGEM	
Origin and characteristics	• Aggregate econometric model • 10 sector interindustry econometric model • Transportation one of the 10 sectors • Drives the system when linked to the LP and I-0 model • Provides the demand side	• 2nd generation LITM • 36 sectors • Not operational 3/80	• Collaboration with U. of Illinois • 110 sectors • Energy output in BTU's • Nonenergy output in dollars • Fuel substitution represented by changes in I-0 coefficients • Serves as an interface between the MACRO and LP models • Time trended I-0 coefficients • Utilizes 1985 estimates of nonenergy I-0 coefficients • Transforms end-use demand to total demand

	MACROECONOMIC INTERINDUSTRY MODELS	INPUT-OUTPUT MODEL
Assumptions	• Population projections • Government tax policy and expenditures • Other exogenous final demand purchases • Unemployment, etc.	• Long-run equilibrium • Factor inputs perfectly mobile • No substitution between energy and nonenergy inputs
Input	From TESOM: • Aggregate energy flows • Oil and gas imports-quantities and prices • New technology levels and production functions	• Energy flows from LP model, converted to I-0 coefficients • Solution GNP and components from macromodel
Output	To TESOM, mapped through "reduced form" of I-0 model: • Aggregate sectoral outputs • Delivered energy flows by sector • Total primary energy consumption To I-0 model: • Solution GNP and components	• Detailed output requirements of the economy To TESOM: • Maps from LITM to TESOM • Initial energy product coefficients

Annotated Bibliography

ANALYSIS OF THE PRIVATE AND COMMERCIAL DEMAND FOR GASOLINE (74-048)

Ramsey, J.B.; Rasche, R.; and Allen, B. 1975. Analysis of the private and commercial demand for gasoline. Review of Economics and Statistics 57(4):502-507.

This model contains econometric equations for gasoline supply, and private and commercial demand. Private demand is specified to a function of gasoline price, price index of train travel, proportion of the population in the 16-24 age group, and prior-period income. Commercial demand is specified as a function of retail gasoline price, a price index of diesel fuel deflated by the price index of truck freight rates, and an index of total ton miles demanded of all freight carriers.

ANNUAL MODEL OF PASSENGER CAR GAS CONSUMPTION IN THE U.S. (73-041)

Chamberlain, C. 1973. Models of gasoline demand. Draft. Cambridge, Massachusetts: U.S. Department of Transportation, Transportation Systems Center report no. RP-SP-21.

Aggregate gasoline consumption is forecast by an econometric equation that has the following independent variables: average miles per gallon, real disposable income, real gasoline price, gasoline consumption lagged, and an index of new-car prices.

AUTOMOBILE AND GASOLINE DEMAND MODEL (75-073)

Taylor, L.D.; Verleger, P.K., Jr.; and Hirtzel, C.W. 1975. Welfare effects of fuel economy policies. Detroit, Michigan: Motor Vehicle Manufacturers Association. NTIS no. PB-256 640/4ST.

In this theoretical model, the demand for gasoline is derived from the demand for motor vehicle transportation. Short-run gasoline demand involves a selected utilization rate of the existing car stock.

AUTOMOBILE FLEET MIX MODEL (74-001B)

Wildhorn, S.; Burright, B.K.; Enns, J.H.; and Kirkwood, T.F. 1974. How to save gasoline: Public policy alternatives for the automobile. Santa Monica, California: Rand Corporation. Prepared for the National Science Foundation NTIS no. PB-242 755.

Aggregate gasoline consumption is calculated by an algorithm using model predictions of miles per gallon and number of vehicles by weight groups with particular technological features, and aggregate vehicle miles traveled. This model is a submodel of the Rand Automobile Energy Conservation Model.

AUTOMOTIVE FLEET FUEL CONSUMPTION MODEL (FUEL4) (77-295A)

Automated Sciences Group, Inc. 1977. Fuel economy models. Silver Spring, Maryland.

This accounting model uses historical data and projections of new registrations, fuel economies, vehicle miles traveled, and survival rates to provide comparisons of various fuel economy scenarios. The stock of cars is divided into five classes: (1) domestic passenger automobiles; (2) imported passenger automobiles; (3) domestic nonpassenger automobiles; (4) imported nonpassenger automobiles (GVW less than 6000 lbs.); and (5) nonpassenger automobiles (GVW 6000 lbs. to 10,000 lbs.).

COMMODITY HIERARCHY MODEL FOR GASOLINE DEMAND (75-285)

Cato, D.; Rodekohr, M.; and Sweeney, J.L. 1975. Capital stock adjustment process and the demand for gasoline: A market share approach. In Economic Dimensions of Energy Demand and Supply, eds. A.B. Askin and J. Kraff, pp. 29-52. Lexington Books.

In this econometric model, aggregate gasoline consumption is calculated by dividing vehicle miles traveled (VMT) by average miles per gallon of the stock. VMT is estimated as a function of the cost per mile (which is a function of gasoline costs and the opportunity cost of automobile travel), income, and the unemployment rate. Average miles per gallon is a vehicle size-class share weighted miles per gallon calculation based on scrappage and usage rates. The model is based on a hedonic classification scheme and a stock-adjustment process.

CONSUMPTION OF GASOLINE BY HOUSEHOLDS (77-087A)

Stucker, J.P. and Kirkwood, T.F. 1977. Economic impact of automobile travel cost increases on households. Santa Monica, California: The Rand Corporation R-1842-NSF/FEA.

Household gasoline consumption is estimated as a function of household income in five equation forms: linear, quadratic, semilog, logarithmic, and power. In addition, household gasoline consumption by income level is calculated based on estimates of average miles per gallon and survey estimates of VMT.

DEMAND MODEL FOR GASOLINE AND RESIDENTIAL ELECTRICITY (74-284)

Houthakker, H.S.; Verleger, P.K.; and Sheehan, D.P. 1974. Dynamic demand analyses for gasoline and residential electricity. American Journal of Agricultural Economics 56:412-418.

The demand for gasoline and electricity by consumers is specified using pooled disaggregated time-series data from different states fitted to dynamic demand functions of the flow adjustment type. The demand for energy is a function of income, price, and the demand in the previous period.

DYNAMIC DEMAND FUNCTIONS FOR GASOLINE WITH DIFFERENT SCHEMES OF PARAMETER VARIATION (78-567)

Mehta, J.S.; Narasimham, G.V.L.; and Swamy, P.A.V.B. 1978. Estimation of dynamic demand functions for gasoline with different schemes of parameter variation. Journal of Econometrics 7:263-279.

These authors study the aggregate demand for gasoline using quarterly state data for 1963.I-1973.IV and a dynamic random coefficients model. They find that the parameters in their model vary across states with a mean income elasticity of .8675 and a mean price elasticity of -.0441.

DYNAMIC LINEAR EXPENDITURE MODEL (72-329)

Phlips L. 1972. Dynamic version of the linear expenditure model. Review of Economics and Statistics 54(4):450-458.

Gasoline and oil expenditure is estimated by an equation allowing for habit formation, stock adjustment, and depreciation. The model is based on refinements of the Geary utility function.

ECONOMETRIC MODELS OF THE DEMAND FOR MOTOR FUEL (75-058)

Burright, B.K., and Enns, J.H. 1975. Econometric models of the demand for motor fuel. Santa Monica, California: The Rand Corporation R-1561-NSF/FEA.

This study produced several econometric equations estimating short-run and long-run fuel demand. The short-run functions are derived from a model of household decisionmaking, while long-run demand focuses on changes in the automobile stock. Different data series and estimation techniques are used.

EEA GASOLINE CONSUMPTION MODEL: ECONOMICS SUBMODEL (75-003B)

Energy and Environmental Analysis, Inc. 1975. Gasoline consumption model, Vol. I. Final Report. Arlington, Virginia. Prepared for the Federal Energy Administration.

This model calculates a preliminary estimate of gasoline consumption by dividing aggregate vehicle miles traveled by average miles per gallon. The average mpg is computed by an algorithm using mpg and VMT by class and vintage. A modified forecast of gasoline consumption is found by an econometric equation with the following independent variables: the preliminary estimate of gasoline demand, real gasoline cost per mile, ratio of new to used car prices, unemployment rate, change in disposable income, and change in VMT per vehicle. The preliminary estimate of gas demand is a function of total VMT and average mpg.

EMISSION/FUEL USE MODEL FOR TRUCKS AND BUSES (78-277)

Jambekar, A.B.; and Johnson, J.H. 1978. Emission and fuel usage computer model for trucks and buses. Warrendale, Pennsylvania: Society of Automotive Engineers, Inc. paper no. 780630.

Gasoline and diesel fuel consumption for nine classes of vehicles (based on weight) is calculated by an algorithm using annual VMT, urban/rural mileage split, and miles per gallon data. The fuel economy estimates are influenced by urban or rural driving, the NOx emissions standards, and technological improvements.

GASOLINE CONSUMPTION MODEL (CHASE) (74-002B)

Chase Econometric Associates, Inc. 1974. Effect of tax and regulatory alternatives on car sales and gas consumption. Final Report. Prepared for the Council on Environmental Quality under Contract No. EQC004, NTIS No. PB-234-622.

Gasoline consumption is calculated by an algorithm using aggregate vehicle miles traveled, cars in use by model year, and model-year miles per gallon. Vehicle miles traveled is forecast by an econometric equation, which has the following independent variables: number of personal passenger vehicles registered, relative real price of gasoline and oil, the change in the consumer price index (all goods and services), average vehicle price lagged two years, and change in aggregate wages and salaries. The 1974-1986 vehicle-class miles per gallon estimates are based on 1973 relationships between inertia weight and fuel economy.

GASOLINE CONSUMPTION MODELS (77-213)

Wong, E.; Venegas, E.C.; and Antiporta, D.B. 1977. Simulating the consumption of gasoline. Simulation 28(5):145-152

Two models of aggregate gasoline consumption were estimated. One model has gasoline consumption as a function of price, income, and prior-period consumption; the other model calculates gasoline consumption from estimates of vehicle miles traveled, cars in use by type, and average miles per gallon by type. The latter was concluded to be the more useful tool for policymakers.

GASOLINE DEMAND MODEL (74-037)

Chamberlain, C. 1974. Policy options: Gas tax vs. gas rationing and/or auto excise tax. Working Paper. Cambridge, Massachusetts: U.S. Department of Transportation, Transportation Systems Center report no. WP-SP-U2-65.

This model is a submodel of the Integrated Transportation Systems Center Automobile and Gasoline Model. Gasoline use per capita is forecast by an econometric equation that has as independent variables: real disposable income per capita, real gasoline price, fleet fuel economy, and lagged gasoline consumption.

GASOLINE PRICE ELASTICITY ESTIMATION (77-358)

Schneider, A.M. 1977. Elasticity of demand for gasoline since the 1973 oil embargo. Energy 2:45-52.

A Box-Jenkins times series model of gasoline sales for the state of California is evaluated for post-1973 years. Elasticities using the model from the pre-1973 and post-1973 are also compared. The estimated elasticity is determined as follows:

$E = 0.2054\ (1 - S/4.78) \pm 0.0378$

where S is the savings due to unemployment and voluntary conservation and is a percent of gallons sold.

GASOLINE PRICE MODELS (78-311)

Bopp, A.E., and Neri, J.A. 1978. Price of gasoline: Forecasting comparisons. Quarterly Review of Economics and Business 18(4):23-33.

Three different methodologies are used to forecast gasoline prices. These are a Box-Jenkins technique, a simple regression technique, and an econometric technique. The authors conclude that the Box-Jenkins technique is better for one-period ahead forecasts while the econometric model is superior for long-run forecasts.

GASOLINE USE MODEL (75-052)

McGillivray, R.G. 1976. Gasoline use by automobiles. Transportation Research Record no. 561.

The per capita gasoline consumption model consists of a single econometric equation with the following independent variables: real gasoline price, new-car registrations per capita, average gasoline consumption per automobile, and lagged passenger car gasoline consumption per capita.

HIGHWAY FUEL CONSUMPTION MODEL (74-006)

Gould, H.H., and Malliaris, A.C. 1974. Highway fuel consumption computer model, (Version I). Final Report. Cambridge, Massachusetts: U.S. Department of Transportation, Transportation Systems Center report no. DOT-TSC-OST-73-43.

A version of this accounting model is a submodel of the Integrated Transportation Systems Center Automobile and Gasoline and Demand Model. The model requires user inputs of fuel economies, vehicle miles traveled by vintage, scrappage rates, cars in use, and new-car market shares by fuel-economy categories. Fuel consumption by category is computed using fuel economy, vehicle miles traveled, and number of vehicles by fuel consumption category and age of vehicle. This model has been superceded by the Automotive Fleet Fuel Consumption Model--FUEL 4 (see above).

HOUSEHOLD SURVEY GASOLINE DEMAND MODEL (78-394)

Archibald, R., and Gillingham, R. 1978. Analysis of consumer demand for gasoline using household survey data. Presented at the meetings of the American Statistical Association in San Diego, California in August 1978.

Archibald, R., and Gillingham, R. November 1978. Consumer demand for gasoline: Evidence from household diary data. Unpublished paper.

Gasoline expenditure equations for one car, multicar, and all consumer units are estimated with survey data. The independent variables deal with gasoline price, changes in gasoline price, number of cars owned, sex, race, two-income families, location of consumer unit, time of interview, education of consumer unit head, age of consumer unit head, members of the consumer unit, work status of consumer unit members, and types of automobiles of the unit.

INCOME AND PRICE LAGS IN CONSUMER-DEMAND ANALYSIS (69-565)

Heien, D.M. 1969. Income and price lags in consumer-demand analysis. Journal of the Royal Statistical Society 132:265-271.

This author econometrically estimates consumer demand for 23 categories of consumer expenditure using distributed lags on income and prices for annual U.S. data for 1946-1965. The six categories that relate to transportation are: petrol and oil; new cars and net purchases of used cars; tires and tubes; user-operated transportation services; local transportation; purchased inter-city transportation minus airline transportation; and airline transportation. Short-run and long-run income and price elasticities, and the length of the lag on both income and price are estimated.

NEW CAR SALES/AUTO OWNERSHIP/VEHICLE MILES TRAVELED (NAV) MODEL (74-001C)

Wildhorn, S.; Burright, B.K.; Enns, J.H.; and Kirkwood, T.F. 1974. How to save gasoline: Public policy alternatives for the automobile. Santa Monica, California: Rand Corporation. Prepared for the National Science Foundation. NTIS No. PB-242 755.

This model is a submodel of the Rand Automobile Energy Conservation Model. Gasoline consumption is computed by dividing aggregate vehicle miles traveled by average fuel economy. Average fuel economy is predicted through the use of an econometrically estimated equation with gasoline price and a dummy variable for federal regulations as independent variables. Vehicle miles traveled is estimated as a function of cars in use, average gasoline price, fuel economy, and a dummy variable for federal regulation.

OIL MARKET SIMULATION MODEL (OMS) (78-397)

Kilgore, W.C. 1979. International Energy Assessment. Washington, D.C.: U.S. Department of Energy. Report no. DOE/EIA-0184/1.

Kincel, K.L.; Kilgore, W.C.; and Rodekohr, M. 1978. Evaluation of future world oil prices. Washington, D.C.: U.S. Department of Energy report no. DOE/EIA-0102/4.

This regional model consists of supply and demand equations for each of seven regions corresponding to the major producing and consuming regions of the world. Supply, demand, and lag parameters are calculated from simulations of the Project Independence Evaluation system (PIES--now the Mid-term Energy Forecasting System) and the International Energy Evaluation System (IEES). DRI macro model simulations are also used in the model.

PROJECT INDEPENDENCE TRANSPORTATION ACCOUNTING MODEL (74-004)

Federal Energy Administration, and Council on Environmental Quality. 1974. Project independence and energy conservation: Transportation sectors. Washington, D.C. NTIS no. PB-248 509/2.

This study examines the distribution of passenger and freight-miles across different modes. Passenger miles are divided into local and intercity, and each is projected using an econometric equation. Freight mile projections are based on industry output projections from an input-output model.

QUARTERLY DEMAND FOR GASOLINE MODEL (73-040)

Data Resources, Inc. 1973. Study of the quarterly demand for gasoline and impacts of alternative gasoline taxes. Lexington, Massachusetts. Prepared for the Environmental Protection Agency and the Council of Environmental Quality.

Using four sets of data, three gasoline consumption equation specifications are estimated using error component estimation techniques. Comparison of short-run and long-run elasticities are also included. The independent variables are various measures of gasoline price (both current and lagged), income (both current and lagged), and lagged gasoline consumption.

REFINERY AND PETROCHEMICAL MODELING SYSTEM (RPMS) (78-336B)

U.S. Department of Energy. 1978. Motor gasoline supply and demand through 1980. Washington, D.C.: U.S. Department of Energy report no. DOE/EIA-0102/11.

This linear programming model complements the Short-Term Petroleum Product Demand Forecasting Model (78-336A) by modifying the supply of gasoline by simulating U.S. refinery operations, including crude distillation, product specification, downstream unit operations, and product blending. In forecasting supplies, the model considers future product demand, product imports, refinery unit capacities and operating rates, and the use of octane boosting additives.

REGIONAL ENERGY AVAILABILITY MODEL (77-366)

Rice, P.L.; Vogt, D.P.; Corey, T.A.; and Pai, V.P. 1977. Energy availabilities for state and local development: A methodological and data overview--1973 data volume. Oak Ridge, Tennessee: Oak Ridge National Laboratory report no. ORNL/TM-5890.

This model allocates national energy use estimates among regions according to socioeconomic activity measures. It uses inputs from INFORUM and Oak Ridge National Lab's MULTIREGION Model. Transportation energy consumption is calculated using population and employment data.

SHORT RUN SUPPLY AND DEMAND MODEL FOR GASOLINE (78-214)

Dahl, C. 1979. Consumer adjustment to a gasoline tax, Review of Economics and Statistics, 61(3).

This structural model, to be used for long-run analysis, contains econometric equations for gasoline supply and demand, stock of cars, vehicle miles traveled, and miles per gallon. The demand for gasoline is specified to be a function of the price of gasoline, income, and stock of automobiles. The purpose of the model is to break the elasticity of demand for gasoline into the price elasticity of demand for VMT and the price elasticity of the mpg of automobiles.

SHORT-TERM PETROLEUM PRODUCT DEMAND FORECASTING MODEL (STPPDFM) (78-336A)

Tuckenmez, E.; Farmer, R.; McDaniel, H.; Everett, C.; and Walton, H. 1978. 1980 motor gasoline supply and demand. Washington, D.C.: U.S. Department of Energy report no. DOE/EIA-0102-32.

This short-term quarterly econometric model estimates the demand for refined petroleum products in each of five regions. The key variables in the gasoline demand equation are population, national income and gasoline price.

SUPPLY AND DEMAND OF ENERGY RESOURCES MODEL (73-351)

Nordhaus, W.D. 1973. Allocation of energy resources, Brookings Papers on Economic Activity (3):529-576.

This linear programming model forecasts the very long run (1970 to 2120 and beyond). The transportation sector is divided into two components in which nonpetroleum-based fuels are substitutable and nonsubstitutable for gasoline. The object of the model is to allocate energy resources over time, space, and uses, such that the discounted costs of meeting a set of final demands are minimized.

TEMPORAL CROSS-SECTION SPECIFICATION OF THE REGIONAL DEMAND FOR GASOLINE (78-211)

Kraft, J., and Rodekohr, M. 1978. Regional demand for gasoline: A temporal cross-section specification. Journal of Regional Science 18(1):45-55.

Using state-level temporal cross-section data, gasoline consumption equations are estimated for nine census regions. The demand for gasoline is estimated as a function of gasoline price, disposable income, and the stock of automobiles lagged one period. A stock-adjustment method is used to find differences among regions and over time.

TRANS (TRANSPORTATION RESOURCE ALLOCATION STUDY) - URBAN MODEL (75-036)

Weiner, E. 1976. Assessing national urban transportation policy alternatives. Transportation Research 10:159-178.

Gasoline consumption is computed by multiplying vehicle miles traveled by average gallons per mile. Vehicle miles traveled enters the model exogenously, and fuel economies are held constant over the model's forecasting period, 1972-1990.

URBAN SIZE AND STRUCTURE AND PRIVATE EXPENDITURES FOR GASOLINE IN LARGE CITIES MODEL (75-566)

Stewart, C.T., and Bennett, J.R. 1975. Urban size and structure and private expenditures for gasoline in large cities. Land Economics LI(4):365-373.

These authors investigate the effects of city size and structure on per capita expenditure for gasoline and lubricants. Using data for 134 SMSAs with populations of 200,000 or greater, they found that gasoline and lubricant demand was: inversely related to city size, rate of city growth, and proportion of workers using mass transit; positively related to the proportion of nonwhite population; and not significantly related to the proportion of the population of driving age, the income variables, nor the price of gasoline. They found some variation by census region. Diversified manufacturing cities and tourist areas consumed more gasoline per capita, while port cities consumed less.

U.S. BUS AND TRUCK POPULATION MODEL (73-043)

Tingley, D.S. 1973. Formulation and development of a United States truck and bus population model with an analysis of the fuel usage and air pollution contributions. Master's thesis, Michigan Technological University.

Mileage per year per vehicle is estimated by class and age, and combined with estimates of average miles per gallon to yield annual fuel consumption. Both gasoline and diesel fuel consumption are predicted.

WHARTON EFA MOTOR VEHICLE DEMAND MODEL, MARK I (78-436)

Loxley, C.J.; Osiecki, T.; Rodenrys, K.; and Thanawala, S. 1978. Revisions to the Wharton EFA automobile demand model, the Wharton EFA motor vehicle demand model (Mark I). Draft. Philadelphia, Pennsylvania: Wharton EFA, Inc.

Aggregate automobile gasoline consumption is calculated through the use of an algorithm that involves three econometric equations. These estimate average miles traveled per vehicle in a particular year, and rural and urban miles traveled per mid-year stock of cars. Urban VMT is estimated as a function of real gasoline cost per mile (using city fleet average mpg), real disposable income per capita, and urban licensed drivers per vehicle. Rural VMT is a function of real gasoline cost per mile (using highway fleet average mpg), licensed drivers per vehicle, income distribution, and total interstate road mileage per vehicle.

WHARTON EFA MOTOR VEHICLE DEMAND MODEL, MARK II (78-437)

Loxley, C.J.; Osiecki, T.; and Rodenrys, K. 1978. The demand for light duty trucks, the Wharton EFA motor vehicle demand model (Mark II). Draft. Philadelphia, Pennsylvania: Wharton EFA, Inc.

Fuel consumption is broken down by type of vehicle: autos, personal-use light duty trucks (LDT), and commercial-use LDT. Consumption is calculated by an algorithm, but depends on econometrically derived equations for urban and rural automobile miles traveled per family; personal-use LDT miles traveled per total vehicle stock; and commercial-use LDT miles traveled per total vehicle stock. The automobile fuel economies are endogenous to the model, while the LDT fuel economies are exogenous.

ABBREVIATIONS AND ACRONYMS

ARC	Annual Report to Congress
BESOM	Brookhaven Energy System Optimization Model, of BNL
BNL	Brookhaven National Laboratory
CAC	Center for Advanced Computation, University of Illinois
CAFE	Corporate average fuel economy
CDC	Control Data Corporation
CPI	Consumer price index
CPU	Central processing unit
DAS	Demand Analysis System, MEFS
DESOM	Dynamic Energy System Optimization Model, of BNL
DFI	Decision Focus, Inc.
DGEM	Dynamic Generalized Equilibrium Model, of DRI
DJA	Dale W. Jorgenson Associates
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DRI	Data Resources, Inc.
EEA	Energy and Environmental Analysis, Inc.
EFA	(Wharton) Econometric Forecasting Associates
EIA	Energy Information Administration, DOE
EMF	Energy Modeling Forum, Stanford University
EMS	Economic Modeling System, of LLL
EPA	U.S. Environmental Protection Agency
EPM	Energy Policy Model, of LLL
EPRI	Electric Power Research Institute
FIPS	Federal Information Processing Standards
GEMS	Generalized Equilibrium Modeling System, of DFI
GNP	Gross national product
HFCM	Highway Fuel Consumption Model, of EEA
HGDM	Highway Gasoline Demand Model, of ORNL
HSRI	Highway Safety Research Institute, The University of Michigan

I-O	Input-output
IEA	International Energy Agency
IEES	International Energy Evaluation System
IFCAM	Industrial Fuel Choice Allocation Model, MEFS
IIASA	International Institute for Applied Systems Analysis
INFORUM	Interindustry Forecasting Model of the University of Maryland
IRT	International Research and Technology Corporation
JFA	Jack Faucett Associates, Inc.
KFA	Kernforschungsanlage (Nuclear Research Laboratory)
LDT	Light-duty trucks
LDVFFCM	Light-Duty Vehicle Fleet Fuel Consumption Model, of EEA
LEAP	Long-term Energy Analysis Program, of DOE
LITM	Long-term Interindustry Transactions Model, of DJA
LLL	Lawrence Livermore Laboratory
LP	Linear programming
LTSS	Livermore Time-Sharing System
MARKAL	Market Allocation Model, of IEA, BNL, and KFA
MDMS	Model Data Management System, of DFI
MEFS	Midterm Energy Forecasting System, of DOE/EIA
MEMM	Midterm Energy Market Model, MEFS
MPG	Miles per gallon
MVMA	Motor Vehicle Manufacturers Association
NARM	National Aggregate Refinery Model, MEFS
NHTSA	National Highway Traffic Safety Administration, DOT
NTIS	National Technical Information Service
ORNL	Oak Ridge National Laboratory
PIES	Project Independence Evaluation System, of DOE
PMT	Personal miles traveled
RDFOR	Regional Energy Demand Forecasting Model, MEFS
SEAS	Strategic Environmental Assessment System, of DOE, EPA
SRI	SRI International, formerly Stanford Research Institute
TECNET	Transportation Energy Conservation Network, SEAS
TESOM	Time-Stepped Energy System Optimization Model, of BNL
TSC	Transportation Systems Center, DOT
TVA	Tennessee Valley Authority
VMT	Vehicle miles traveled