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Alternative Approaches to Energy Modeling

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by

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1.0 INTRODUCTION

The effects of government and private sector energy policies are varied and interrelated. Before implementing research and development programs, new technologies, environmental and price regulations, import quotas, and other energy-related policies, the consequences of these programs must be identified and quantified on a regional basis. To evaluate the regional impacts of energy policies, we need to consider production costs, transportation costs, and the location of reserves, as well as the demands for energy and nonenergy goods. Developing techniques for analyzing these factors was the objective of many previous research efforts. The strengths and weaknesses of the resulting models are discussed in this paper and areas for future research are outlined. Only those models that consider more than one fuel and sector (i.e., residential, utility, etc.) are reviewed.

The models examined are the Battelle Columbus-EPA Energy Quality model,(1) Baughman's Dynamic Energy System model,(2) the Brookhaven National Laboratory Energy models,(3) the Energy Management Simulation and Analysis System,(4) the Hudson-Jorgenson Energy model,(5) Kalter's Parametric Models of Fossil Fuel Markets,(6) the Project Independence Evaluation System,(7) and the Wisconsin Energy model.(8)

Most of these energy models have been formulated for use on a national level. Because of differing energy markets in various regions of the country, these national models may be inappropriate for assessing regional energy-policy impacts. Regional models may also be designed inadequately if they do not account for interregional transactions of energy-related goods.

A framework for evaluating current models is presented in the next section. It identifies features that should be included in a comprehensive and logically consistent regional energy model. In Section 3 the features of the eight energy models reviewed are summarized. These models are compared and their strengths and weaknesses are discussed. Areas for future research are identified and the analytical techniques incorporated in each model are delineated. In Section 4 potential uses of these models are discussed.

2.0 FRAMEWORK FOR EVALUATING REGIONAL ENERGY MODELS

An evaluation of energy models cannot be conducted without first defining the criteria on which the evaluation is based. Three sets of criteria are used: model comprehensiveness, economic aspects of the model, and model capabilities. The model comprehensiveness section defines the scope of the models in terms of the spatial, energy-supply, and energy-demand details. The economic aspects of the models considered are the determinants of total demand and supply, interfuel competition, and interregional competition. The ability of a model to simulate the effects of policy or technology changes are considered in the capability section. These three sets of criteria, therefore, define the eight characteristics used to evaluate each model. These characteristics are listed in Table 1. In this section, the criteria used and the reasons why these model characteristics are considered desirable are presented. To aid in the discussion of the importance of these criteria, a schematic of an energy model is provided in Figure 1.

TABLE 1. Criteria for Evaluating Energy Models

Criteria	Examples
Comprehensiveness	
Spatial Detail	States, census regions, nation
Supply-sector detail	Coal, oil, natural gas, high- and low-sulfur fuels
Demand-sector detail	Industrial, transportation, lighting, space heating
Economic Aspects	
Total demand and supply determinants	GNP, income, energy prices, reserves
Interfuel competition	
Interregional competition	
Capabilities	
Policy actions	Import quotas, environmental regulations, conservation
Technology changes	Solar energy, coal gasification, electric cars

The first set of criteria (model comprehensiveness) is important because the models should be useful in assessing the regional and sectoral impacts of policy and technology changes on energy production and consumption. Without adequate detail in the model, these separate effects cannot be evaluated. Furthermore, the impacts estimated with a highly aggregated model may err significantly because they do not account for variations in regional and sectoral markets.

The minimum level of spatial detail is not easily defined since it depends in part on the policy under consideration. For example, the environmental impacts of alternative energy consumption patterns may be highly localized within a particular state. In this situation a state-level analysis may be insufficient. On the other hand, some technology changes or federal policy actions may have significant regional impacts at only the "Census Region" level of aggregation. Because of the importance of spatial detail in many analyses and the varying levels of detail required, and because it is generally easier and more accurate to aggregate data, a model that has greater than a Census Region level of detail is desired.

Because there are practical cost and data limitations, a model that considers coal, oil, and natural gas as primary fuels, and electricity as a secondary energy source, is considered to have adequate supply detail. Without at least this level of detail, interfuel competition cannot be modeled. On the demand side, a model should include industrial, residential, commercial, and transportation demands. The industrial sector should include manufacturing, agricultural, and utility energy demands. These levels of detail are viewed as minimum requirements for a comprehensive energy model.

Since most energy-related policy actions or technology changes affect the energy market, an energy model should simulate market behavior adequately. The demand for nonenergy goods affects energy demands in two ways: (1) the demand for energy is in part a derived demand resulting from the use of energy as an input in the production of goods and services; and (2) energy and nonenergy goods compete against each other; i.e., given a fixed budget, the more people spend on energy, the less they will be able to spend on nonenergy goods.

Because economic prosperity is strongly related to energy prices, an energy model should reflect this relationship. That is, the model should consider the feedback effect of energy prices on the demand

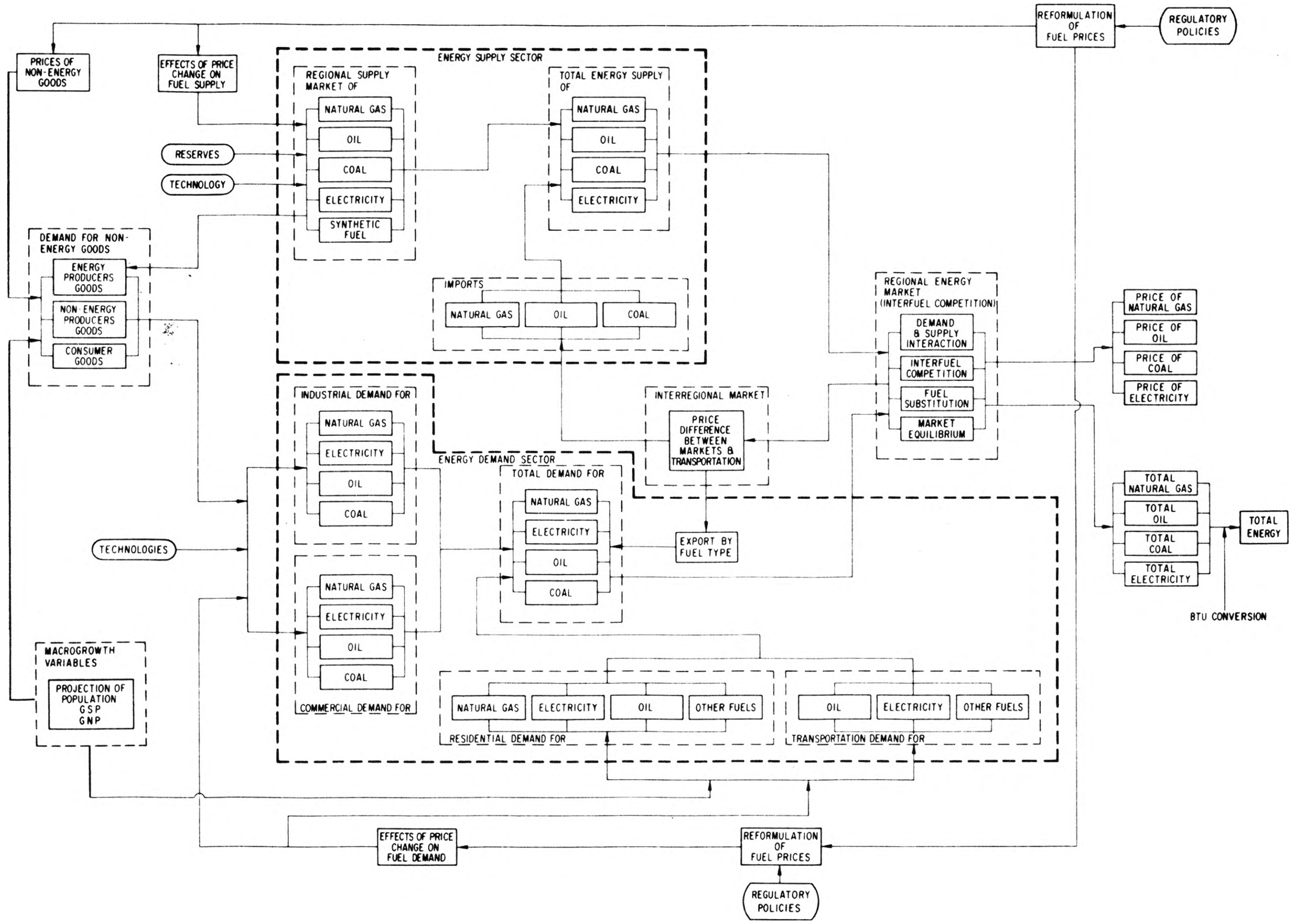

Figure 1. Regional Energy Model System

for goods and services (as shown in Figure 1). Energy prices also affect levels of exploration, the economic feasibility of alternative production processes, and ultimately the supply of energy. These relationships should be explicitly accounted for in a comprehensive energy model.

Given the total demand and supply of energy, market shares of each fuel must be determined. Market shares are a function of relative fuel prices, stocks of capital goods, consumer preferences, and other variables that affect interfuel competition. Because the availability of fuels at a given market price varies significantly between regions of the country, the interfuel competition aspects of the model may be meaningful only if the model is regionalized. To emphasize this point, the interfuel competition aspect of the schematic model in Figure 1 is labeled as a regional energy market.

Interfuel competition is an essential part of any model used to analyze the impacts of oil import quotas, sulfur dioxide control regulations, strip-mine reclamation regulations, deregulation of natural gas prices, coal gasification technology advances, and other perturbations of the energy market that will affect the price of some fuels more than others. A model that does not take into account market adjustments resulting from these policies may estimate incorrectly their relative advantages or disadvantages.

Equally important to interfuel competition is interregional competition. Differences between regions include costs of production, quality of the fuels, and proximity to markets. Production costs may be different because of the type of mining used (strip- vs. deep-mine) or the depth or level of depletion of the reserve. Varying production costs affect the prices suppliers are willing to accept for their products. The quality of the fuel is important when environmental regulations are being considered or when the production process dictates special fuel characteristics. In particular, the heat values and sulfur and ash contents of the fuels are important. Because of environmental regulations, some sources of energy cannot be used without expensive control equipment, the net effect being an increase in the cost of using those sources of energy. Proximity to markets has been a major factor in regional differences in fuel consumption patterns. In some instances, transportation costs represent the major portion of the selling price of a fuel. To be capable of simulating interregional competition, the model must consider all competing regions, hence a national or state model would clearly be inadequate for this purpose.

The final set of criteria, model capabilities, deals with the problems to which the models can be applied. Policy options, which consist of regulatory, funding, and priority-setting decisions, as well as technology advances, will affect energy supplies and demands and thus the price that must be paid for energy. In this analysis, a model that does not endogenously simulate the effects of policy or technology changes is classified as one that does not have this capability. Some models can simulate the energy impacts of changes in the economy if the resulting price, cost, demand, GNP, etc., changes are provided exogenously. Such models are easily adapted for policy analysis if auxiliary programs are constructed to simulate the impacts of the policy on these independent variables. Finally, some models may have restrictive assumptions that preclude their use for policy analysis.

3.0 STRENGTHS AND WEAKNESSES OF EXISTING ENERGY MODELS[9]

In Section 2, eight criteria were defined for reviewing the energy models. None of the models reviewed satisfy all of these desirable attributes. Unfortunately, a simple summary table identifying the criteria satisfied by each model cannot be constructed because some of the models only partially satisfy some of the criteria. Additionally, because the approaches used in the models differ, a comparison of models satisfying the same criteria becomes difficult. Finally, a complete evaluation of these models cannot be made without information on their accuracy, ease of use, computational efficiency, and other operating characteristics.

Although simple comparisons cannot be made, two summary tables have been constructed. These tables will facilitate the discussion on the state of the art of energy models and help identify areas of future research. Table 2 summarizes the economic aspects of the models. It provides a quick check of the approaches used and some of the primary data sources or driving parameters required to simulate the economic behavior within the model. Table 3 summarizes the comprehensiveness and capabilities of the models. The table identifies the principal independent variables used to drive the model when policy or technology changes are simulated. In addition, the types of perturbations that the model can simulate endogenously are listed.

Total energy demands either are provided exogenously or are estimated using trends, econometric techniques, or input/output techniques. Energy consumption is usually assumed to be a function of GNP, income, population levels, production output, or other demographic-economic variables. Energy prices (or an energy price index) are used as determinants of energy demands in the Kalter, PIES, H-J, and EMSAS models. However, none of the models explicitly considers the impacts of energy costs on the general economy. The H-J model can account for energy price effects on the economy if the prices calculated in its interindustry model are fed back into its macro-growth model as a change in the price deflator factors.

The demand for energy will change as energy costs change due to both substitution and income effects. Most models do not separate these effects. Of particular importance is the income effect and its influence on the rate of growth of the economy. Since increases in energy costs will most likely increase the costs of most commodities, the buying power of the consumer will be reduced. If this reduction is significant, it will result in a slowing down of the economy, reducing the derived demand for energy, and tending in turn to reduce energy prices. Therefore, if the income effects are not properly accounted for, a model will overestimate the demand <u>and</u> the price of energy. This is an area in which the state of the art could be improved.

The factors that determine the supply of fuels such as the levels of reserves, development and production costs, and exploration activities are not explicitly

TABLE 2. Summary of the Economic Aspects of Energy Models

MODELS	ENERGY DEMAND	ENERGY SUPPLY	INTERFUEL COMPETITION				INTERREGIONAL COMPETITION	
			Method	Market Lags (Dynamics)	Sectors	Fuel Prices	Method	Transportation Cost
Battelle Columbus - EPA Energy Quality Model	NPC's forecast for U S AQCR forecast taken from 1973 study by M C Cook Sartoreus and Company Other exogenous sources	Stepwise supply function applying the "minimum acceptable selling price" concept No exploration	Linear Programming	Power Plants constrained to present fuel use capabilities	Electric Utilities	Minimum acceptable selling prices are provided exogenously and adjusted upward based on shadow prices obtained from LP model	Linear programming (Objective function minimizing total systems energy costs)	Rates provided exogenously
Baughman's Dynamic Energy System Model	Demand by sector provided exogenously	Parametric engineering supply functions Exploration activity provided exogenously	Log linear equation which is price sensitive (Partly econometric and parametric)	Total demand assumes that some consumers are "locked in" to particular fuel, i e , demand for fuel is not price sensitive Supply model assumes exponented delay functions	Electric Utilities Residential/ Commercial Industrial	Equals point on supply curve corresponding to a given demand for each fuel	Not considered	Assumes that costs are constant multiples of supply prices of each fuel
Brookhaven NL Models ● Basic	Exogenously provided from other studies, extrapolation, or user's assumption	Exogenously provided from other studies	None	Not considered	Not considered	Exogenous	Not considered	Rates taken from FPC 1970 <u>National Power Survey Report</u>
● Modified	Same as above	Exogenously provided elasticity of supply (presently set at .5)	Linear Programming	Assumes no fuel conversion until capital stock has reached a given age	By functional activities (end-use) of Residential/Industrial Electrical Utilities	Derived from exogenously provided supply functions and shadow prices of LP model	Not considered	Rates taken from FPC 1970 <u>National Power Survey Report</u>
Energy Management Simulation and Analysis System (EMSAS)	Based on trends or exogenously provided (for industrial sector, it can be estimated using price sensitive econometric equations)	Parametric engineering - simulation equations (oil, natural gas) Exogenous (coal) Exploration is price-sensitive, probability of success based on historical trends	Trend analysis Econometric Market share equation (Varies by sector)	Portion of demand is assumed to be market sensitive This portion is provided exogenously Gas and oil supply models allow for lag between time when they are committed to production	Industrial Residential (single unit homes) Electric Utilities	Future prices trended or provided exogenously	User determines interregional flow of energy	Rates provided exogenously
Hudson-Jorgenson Model (H-J)	Input-Output and Macro Growth Model (technical coefficients and final demand components estimated by econometric equations)	Exogenously provided from other studies I/O coefficients	Econometric equations	Macroeconomic model is dynamic Comparative statics	Agriculture, manufacturing, transportation, communications, coal mining, crude petroleum and natural gas, petroleum refining, electric utility, and gas utility as intermediate demand, and residential, government, and commercial as final demands	Market clearing prices dependent upon demand and supply conditions	Not considered	Not considered
Kalter's Parametric Model	Dynamic parametric equation	Dynamic parametric equation	Parametric equation (substitution occurs if fuel prices differ by fixed percentage)	Assumes short-run and long-run elasticities for demand and supply (with response rate)	All sectors simultaneously	Market clearing prices dependent upon demand and supply conditions	Not considered	Not considered
Project Independence Evaluation System (PIES)	Econometric equations	Modified NPC parametric equations used to calculate the "minimum acceptable selling price" by the discounted cash flow technique (oil, natural gas) Step function where price is the "average minimum acceptable selling price" (coal) Exploration activity for natural gas and oil is provided exogenously	Market share equation (linear logit) Linear Programming	Econometric demand models developed with long-run and short-run elasticities	Residential/Commercial Industrial (Market Share) Electric Utilities (Linear Programming)	Equals market clearing price where demand equals supply	Linear Programming (objective function minimizing total systems energy costs)	Rates provided exogenously or determined by Task Force
Wisconsin Energy Model (WISE)	Trend analysis Engineering, parametric models User defined	Exogenous	Assumed change in energy intensiveness coefficients (Industrial) Assumed mixes of fuel (Electric Utilities)	Explicit consideration of age of capital equipment	Industrial Electric Utilities	Published prices from various sources	Not considered	Not considered

TABLE 3. Summary of Energy Model Comprehensiveness and Capabilities

MODELS	SPATIAL	SUPPLY	DEMAND	POLICY		TECHNOLOGY	
	Level	Fuels	Sectors	Type	Independent Variables Affected	Type	Independent Variables Affected
Battelle Columbus - EPA Energy Quality Model	92 Supply districts of fuels 233 AQCR demand region	4 grades of coal by sulfur content Natural gas Distillate and residual oil	Residential/Commercial/Industrial Electric Utilities	SO_2 regulations	Supply availability Control costs	Power plant SO_2 Controls Fuel production technology improvements	Control costs Fuel prices
Baughman's Dynamic Energy System Model	U S	Coal Natural gas Oil Nuclear Hydro	Residential / Commercial Industrial Transportation Electric Utilities	Directly affecting price (eg, tax, tariff)	Price	Directly affecting price	Price
Brookhaven NL Models ● Basic	U S N Y City	Coal Natural gas Oil (distillate, residual, jet-fuel, gasoline) Nuclear Hydro	Residential Commercial Industrial Transportation (by end-uses) Electric Utilities	Parametric reduction of appliance or boiler efficiencies	Efficiencies	Parametric changes	Technology Trajectories
● Modified	U S	Same as above	Same as above	Environmental regulation Directly affecting price	Constraints Price	Directly affecting cost	Price
Energy Management Simulation and Analysis System (EMSAS)	State (Industrial demand) Census Region demand Supply estimates on national basis which are allocated to "fuel districts"	Coal (only utility usage) Natural gas Oil Nuclear Hydro	Residential/Commercial Industrial (2-digit SIC) Electric Utilities Natural gas feed stocks	SO_2 regulation Directly affecting price (eg, tax, tariff)	Price Control Costs	Directly affecting price Sulfur control technology	Price Costs
Hudson-Jorgenson Model (H-J)	U S	Coal Natural gas Petroleum Nuclear Hydro	9 intermediate sectors Personal consumption Government Investment Exports	Directly affecting price (eg, tax, tariff) Directly affecting macroeconomic variables	Energy price Real income	Directly affecting price	Price Productivity Real income
Kalter's Parametric Model	U S	Coal Natural gas Oil	All sectors simultaneously	Directly affecting price (eg, tax, tariff)	Price	Directly affecting price	Price
Project Independence Evaluation System (PIES)	U S and Census Region Demand Supply districts of fuels	Coal Natural gas Oil Nuclear Hydro Synthetic fuels, Solar and Geothermal	Residential/Commercial Industrial (2-digit SIC) Transportation Electric Utilities (some end-uses)	Directly affecting price (eg, tax, tariff)	Price	Directly affecting price	Price
Wisconsin Energy Model (WISE)	State of Wisconsin	Coal Natural gas Oil (distillate residual, kerosene, LPG, gasoline) Nuclear Hydro	Residential Commercial Industrial (2-digit SIC) Transportation Electric Utilities Agriculture (by end-uses)	Parametric change in engineering efficiency Regulations such as building codes	Energy intensiveness coefficients	Changes in engineering efficiency	Engineering parameters used in demand sub-models

considered in the Energy Quality, BNL Basic and Modified, H-J, Kalter, and WISE models. Although all of these models assume that supply will be sufficient to meet demand, the WISE and Basic BNL models do not relate supply to fuel prices. The others simulate the response of supply to price parametrically rather than econometrically. In general, these models implicitly account for changes in supply by variations in fuel prices, a minimum acceptable selling price, the ratio of reserves to production, and/or I/O coefficients. Some of these variables, however, are provided exogenously as indicated in Table 2.

The Baughman, EMSAS, and PIES models explicitly consider the effect of exploration and development on future production of energy resources. The Baughman and PIES models exogenously determine exploration activity levels. EMSAS estimates the impact of prices, and other variables, on exploration activity for oil and natural gas, using historical relationships and parametric analysis.

Electricity supply determinants are considered in all of the models, except the Basic BNL and Energy Quality models. The other models assume that supply will meet demand and, therefore, the required production capacities are determined by estimating electricity demands. The PIES model incorporates an LP Program that chooses the least-cost combination of existing and incremental plant capacity to meet the demand for electricity. Although many of the models estimate electricity demands as a function of the prices of electricity and other fuels, only the H-J model considers the effects of fuel prices on the price of electricity.

As indicated in Table 2, only the WISE and the Basic BNL models do not consider interfuel competition. The most popular approaches for simulating interfuel competition are econometric techniques and linear programming. The primary variables used to determine market shares are fuel prices, which are provided exogenously or are based on trends in the EMSAS model. The other models that consider interfuel competition generate fuel prices endogenously through the supply and demand interface. The interfuel competition aspects of some of the models are restricted to a few sectors as shown in Table 2. Although Kalter's model considers all economic sectors, the model only calculates aggregate market shares; i.e., the market shares within each sector are not calculated.

A common problem in analyzing the dynamics of interfuel competition is accounting for market lags. These occur, in part, because capital equipment is often replaced when one form of energy is substituted for another. The choice between fuels must, therefore, include consideration of the capital replacement costs in addition to fuel prices. None of the models reviewed explicitly simulates the capital replacement decision. Most of the models account for market lags by separating demand into fixed and market-sensitive components in which the fixed component is a function of the characteristics (usually age) of capital stocks, or by estimating long-run demand elasticities, which implicitly account for these lags. Lags on the supply side are simulated using long-run elasticities, delay functions (e.g., exponential), or parametrically defined delays in production. Because of the importance of market lags in forecasting future energy demand and supply, more emphasis should be devoted to this problem.

Another area in which the existing models could be significantly improved is in dealing with interregional competition. Only the Energy Quality, PIES, and EMSAS models are multiregional. The Energy Quality model is limited because it considers competition between suppliers as independent of demand, i.e., demand is fixed. EMSAS, although regional, does not consider interregional competition. Therefore, only the PIES model attempts to simulate the effects of interregional competition from both the demand and supply sides.

Interregional competition is modeled in the PIES and Energy Quality models by using linear programming to minimize the delivered price of fuels. The key parameters in the model are transportation costs. The PIES model allows for different modes of transportation for each fuel. The Energy Quality model assumes that only one mode of transportation will be used for each fuel.

The most common levels of regional detail are national and census regions. The EMSAS model does estimate industrial energy demands by state and the Energy Quality model has a substate level of detail. The primary deterrent to regionalization is the lack of region-specific data. Some model structures, however, are more conducive to regionalization than others, because of their relative simplicity or less restrictive data requirements. Econometric and parametric models, such as the Basic BNL, Kalter, WISE, Baughman, PIES, and EMSAS models, are the easiest to regionalize. That four of these models have been used on a regional level exemplifies this fact. However, these techniques are not as conducive to modeling interregional flows of energy. Since this is primarily a transportation problem, a linear programming formulation, as used in the Energy Quality and PIES models, seems appropriate. The most difficult models to regionalize are those that use input/output analyses. These are the H-J and the Modified BNL models. Therefore, before these approaches should be adopted for regional studies, the advantages of using I/O must be weighed against the difficulties (data acquisition, model efficiency, etc.) of regionalization.

Because of the selection process used to identify models, most of the models surveyed have good fuel supply detail. Except for EMSAS, all of the models consider coal, oil, and natural gas as primary fuels and electricity as a secondary source of energy. EMSAS has a strong natural gas bias, but does consider oil, coal, or electricity for some sectors. The weakest aspect of the model is related to coal.

On the demand side, very few of the models are complete. The three demand sectors missing most often are the transportation, fuel oil and natural gas feed stock, and agricultural sectors. The H-J model considers most sectors, but the industrial sector is not sufficiently detailed. The EMSAS, PIES, and WISE models have good industrial (2-digit SIC) detail. EMSAS also provides for natural gas feed-stock demands; the BNL and WISE models have the best, and PIES has some end-use detail.

Although many of the authors claim their models are useful for evaluating energy policies or technology changes, these claims are often overstated. If the effects of a policy or technology change on fuel prices, costs, and availability are known, then some of the models can be used to estimate the ramification of these changes on the energy system. Only the Battelle-EPA and EMSAS models have subcomponents that simulate the effects of policy on these key parameters. The Battelle-EPA model is limited to sulfur dioxide regulation of fuels. The EMSAS model considers sulfur dioxide regulations and also has provisions for simulating the impacts of new technology. Most of the models, however, are capable of analyzing the impacts of policies that directly affect energy prices, such as taxes and price regulations. Others can simulate the effects of policies parametrically. These models with the least evaluative capabilities are the Basic BNL, Kalter, and WISE models. These models can be used to conduct only parametric studies and some regulatory policies. Yet, with sufficient modification, the BNL and WISE models can be quite useful because of their greater end-use detail.

4.0 SUMMARY AND CONCLUSIONS

This review should clearly indicate that none of the existing energy models is capable of evaluating all of the present energy issues. Furthermore, development of a tool of that degree of comprehensiveness is not recommended. To begin with, the task may be impossible. Even if it were possible to simulate the impacts of all existing energy issues, it is unlikely that all future issues could be evaluated with the model. In addition, a large comprehensive model designed for multipurpose use would most likely not only be economically inefficient, but its very complexity would make more difficult the interpretation of its results. Rather than developing a single multipurpose energy model, we recommend that a library of techniques be developed and maintained. In this way the analyst will be able to select the technique that best fits his present needs, thus avoiding excessive data collection, computer, and analytic costs.

This library should consist of two types of models. The first, referred to as "local impact models," provides a great deal of detail on end-use demands for energy; production processes of supplies; and/or environmental, social, political, and economic impacts. These models can be applied to state or substate areas. Energy requirements under a given national policy or technology scenario are provided exogenously to these models. The function of the microscale models is to simulate the impacts of decisions that affect only local markets, and to estimate the impacts of national policy or technology changes at the local level, where it has the most meaning. The second class of techniques, referred to as "national synthesis models," are designed to estimate energy supplies and demands as a function of decisions that affect the national energy market. These techniques should be multiregional and should include the entire domestic energy market with at least the Census Region level of detail provided. Three of the eight models reviewed can be classified as local impact models. These are the WISE, Basic BNL, and Energy Quality models. The other five are national synthesis models.

These two classes of models could be coupled in a number of ways. As suggested above, the national synthesis models could provide regional energy supply and demand estimates consistent with national goals and policies and consistent with each other. That is, the output of the national synthesis models would be used as inputs to the local impact models. If, however, a regional policy were expected to have an impact on the national energy market, then the output of the local impact models would be used as inputs into a national synthesis package to estimate the implications of local policy on the national energy market. In other words, the models could be used in conjunction with each other as dictated by the problem being analyzed.

This review indicates that existing models are deficient in two important areas: (1) consideration of interregional competition, and (2) integration of energy supply and demand forecasts with economic growth. None of the models reviewed is truly multi-regional, i.e., competing supply region interactions and competing demand region interactions are not considered. The PIES model is the closest to having this capability. In respect to the latter point, the effects of energy prices on economic growth are not considered in any of the models, and only a few provide for the effects of energy prices on total energy demands. The most advanced model in this respect is the Hudson-Jorgenson model. If future research efforts are devoted to these issues, then the value of energy models will be greatly enhanced.

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BIOGRAPHY

Alan S. Cohen received his Ph.D. in Industrial Engineering and Management Sciences from Northwestern University in 1971. He is presently an Environmental Systems Engineer at the Energy and Environmental Systems Division, Argonne National Laboratory, and project director for the Environmental Pollutants and the Urban Economy Program sponsored by the National Science Foundation. Other work has involved air pollution, water quality and solid waste management planning for the State of Illinois and major research responsibilities with energy, land use and socio-economic projects. Dr. Cohen has recently coauthored a book entitled Residential Fuel Policy and the Environment, Ballinger Publishing Co., Cambridge, Mass. (Coauthors, G. Fishelson and J.L. Gardner)

Kenneth W. Costello received his B.S. and M.A. degrees in Mathematics and Economics respectively from Marquette University. He has been an Assistant Economist at Argonne National Laboratory since 1974. His previous research areas include the development of an econometric model for Softwood lumber industry, and a supply analysis of the western coal industry. His present research centers on the utilization of econometrics for forecasting regional energy demand.