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ECONOMIC AND TECHNOLOGICAL MODELS
FOR EVALUATION OF ENERGY POLICY *

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Abstract: Models for energy policy assessment have been developed using both process analysis and econometrics. The process approach provides for the incorporation of information on future technological and structural changes based on detailed engineering studies. The econometric approach is well adapted to the description of aggregative consumer behavior and economic activity. This paper presents a new approach for policy assessment, integrating process analysis and econometric models that have been used extensively in energy policy analysis and technology assessment. We illustrate the application of this approach by an analysis of a national research, development, and demonstration plan for the United States.
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1. Introduction.

The Arab oil embargo of 1973 and the extraordinarily cold winter of 1977 are part of a series of events that has elevated energy policy in the United States to the highest level of social priority. A new Federal government agency, the Federal Energy Administration, has been established to administer price controls and associated allocation mechanisms adopted in the face of higher world oil prices. A second agency, the Energy Research and Development Administration, has been established to co-ordinate research, development, and demonstration projects for the energy sector. These agencies will now be incorporated into a new cabinet-level Department of Energy. Energy research and development in the private sector has expanded with increased financial support from both government and private sources.

The guidelines of a national energy policy for the United States have emerged; detailed programs are being developed and implemented. To preserve flexibility in the face of uncertainty a continuous assessment of existing programs is required. Analysis is needed for likely impacts of such policy measures as price controls, taxes to stimulate energy conservation in the private sector, government support to generate additional conventional energy supplies, and government sponsored research and development programs, directed toward providing new technology for energy production, conversion, and utilization. The evaluation of new and existing energy policies must incorporate information from detailed engineering studies of specific technologies emerging from research and development programs and must include the assessment of policy impacts on the structure of the energy sector and on the overall level and composition of economic activity.

Alternative models for energy policy assessment have been developed on the basis of both process analysis and econometrics. In the process analysis approach energy flows and energy conversion processes are described in physical terms. The description need not be limited to a particular technology, but can encompass the entire system for the production and utilization of energy. In the econometric approach the representation of technology is based on behavioral and technical responses of production patterns to alternative prices; a similar approach can be employed for the representation of consumer preferences. Flows of economic activity, including energy flows, are described in terms of economic accounts in current and constant prices.

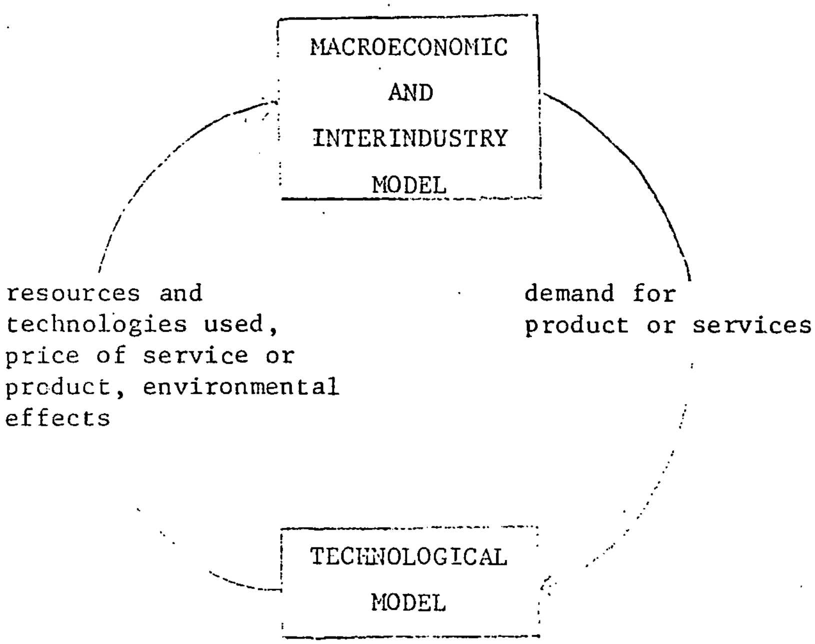
The process approach provides for the incorporation of information from detailed engineering studies, including studies of technologies that are under consideration for future implementation. This approach is well adapted to the description of the energy sector; however, the representation of aggregate economic activity by means of process analysis is infeasible. The econometric approach is well adapted to the description of aggregate economic activity in summary form and provides for the analysis of policy impacts on the overall level of economic activity and its distribution among industry groups or groups of consumers. However, this approach is infeasible for the study of technologies that are not already in use or for the study of consumer preferences for commodities not already in existence.

A satisfactory framework for the assessment of the full range of alternative energy policies requires an approach that encompasses both process analysis and econometrics. Since the output of the energy producing industries is largely consumed by other industries rather than by final consumers such as households, governments, and the rest of the world, a natural focal point for the study of the impact of energy policy is the matrix of interindustry transactions, representing flows of commodities, including energy, among industrial sectors. For the energy sector these transactions can be expressed in economic terms, in current and constant prices, to provide a link with econometric models. These energy sector transactions can also be expressed in physical terms, in British thermal units, to provide a link with process analysis models. Using both forms for the expression of energy flows, process analysis and econometric modeling can be combined.

The purpose of this paper is to present a new approach for the assessment of energy research, development, and demonstration policy, integrating process analysis and econometric models that have already been used extensively in energy policy analysis and technology assessment. The first component of the approach is an econometric model of interindustry transactions together with a macroeconomic model, presented in Section 2, developed for the Energy Policy Project. The second component is a process analysis model of the energy sector, also presented in Section 2, developed for the Energy Research and Development Administration. We present the combined econometric and process analysis approach in Section 3; a preliminary model based on this approach has been employed by the Energy Research and Development Administration in the construction and analysis of a national research, development, and demonstration plan. In Section 4 we employ the results of a policy analysis prepared for the national plan to illustrate the application of this approach to energy policy assessment.

The methodology for our combined econometric and process analysis model is illustrated in Figure 1. The econometric model reflects economic impacts at the aggregate level, including changes in final demand and employment, that result from changes in energy policy. The process analysis model determines the optimal use of resources for a given energy policy and a given economic environment. Our methodology can be applied to a wide range of national policy questions where the technological component is significant. In any policy area involving technology it is necessary to make explicit the relationships between choice of technology and the economic and social environment. Process analysis is the most appropriate methodology for describing alternative technologies; econometrics provides a basis for describing the economy as a whole. Our model represents the first attempt to implement a model that combines the advantages of both methodologies.

Figure 1. Combined Econometric and Process Analysis Model.



Reflects changes in final demand, GNP, and employment in response to economic and technical policies, resource availability, and technological change.

Given set of alternative technologies, determines optimal use of resources and technologies with respect to specific objectives, constraints, and requirements. Indicates environmental effects.

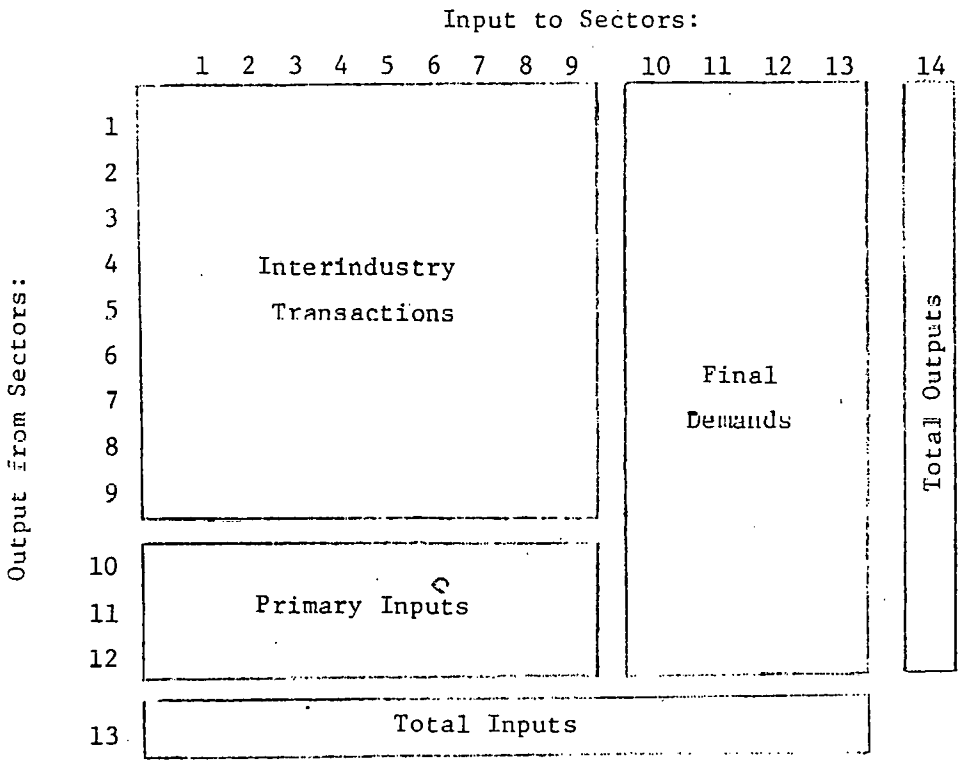
2. Econometric and Process Analysis Models.

The first component of our model for the analysis of energy research, development, and demonstration policy is an econometric model of interindustry transactions, developed by Hudson and Jorgenson (1974a). This model is based on a system of accounts for the private domestic sector of the U.S. economy, including final demand, primary input, and interindustry transactions in current and constant prices. By means of this accounting system we can trace the process of production for energy and non-energy products from the purchase of primary inputs through all stages of intermediate processing to deliveries to final demand. The accounts in constant prices correspond to commodity flows in physical terms. For energy sectors (or industries) these flows can be measured in physical units such as tons of coal, barrels of petroleum, and thousands of cubic feet of natural gas, or, alternatively, in energy units such as British thermal units (Btu's).[1] The accounts in current prices correspond to flows in financial terms and can be used to generate financial accounts for each industry group included in the model. For energy and non-energy sectors the prices can be expressed as index numbers; for energy sectors the prices can also be given in terms of physical or energy units.

In our system of accounts the private domestic sector of the U.S. economy is divided among nine industry groups, including five groups within the energy sector -- coal mining, crude petroleum and natural gas, petroleum refining, electric utilities, and gas utilities. Our representation of the energy sector provides for an analysis of the impact of energy research, development, and demonstration policy on the industrial sectors directly affected by changes in energy technology. By incorporating final demand and four industry groups making up the non-energy sector we can assess the impact of changes in energy technology on the sectors that consume energy products. Our complete system of accounts is represented in diagrammatic form in Figure 2. The nine industry groups included in the accounting system are listed in Figure 2. In this Figure we also list three categories of primary inputs -- capital services, labor services, and imports -- and four categories of final demand -- consumption, investment, government purchases, and exports.

In our system of accounts for interindustry transactions, each industry group purchases primary inputs and intermediate inputs produced in each of the nine industrial sectors. These purchases are represented as columns of the matrix of interindustry transactions in Figure 2. Intermediate inputs include five types of energy -- coal, crude petroleum and natural gas, refined petroleum, refined natural gas, and electricity -- and four types of non-energy products. The output of each industry is distributed to final demand and to intermediate demand by each of the nine industrial sectors. These deliveries are represented as rows of the matrix of inter-industry transactions in Figure 2. The rows corresponding to the five industries that make up the energy sector include deliveries of energy products to energy and non-energy sectors and to final demand. Similarly, the rows corresponding to the four industries of the non-energy sector include deliveries of non-energy products.

Figure 2. Interindustry Transactions in the Econometric Model.



Industry Sectors:

1. Agriculture, Nonfuel Mining, and Construction.
2. Manufacturing, Excluding Petroleum Refining.
3. Transportation.
4. Communications, Trade, and Services.
5. Coal Mining.
6. Crude Petroleum and Natural Gas.
7. Petroleum Refining.
8. Electric Utilities.
9. Gas Utilities.

Primary Inputs:

10. Imports.
11. Capital Services.
12. Labor Services.

Final Demands:

10. Personal Consumption Expenditures.
11. Gross Private Domestic Investment.
12. Government Purchases of Goods and Services.
13. Exports.

Our econometric model of interindustry transactions includes balance equations between supply and demand for the products of each of the nine industrial sectors included in the model.[2] These balance equations state that the output of each sector in constant prices must be equal to deliveries of this output to all nine industrial sectors and to all four categories of final demand. For energy products the balance equations assure that for each form of energy, the energy units produced must be equal to the energy units consumed by all industrial groups and by final demand. Similarly, our econometric model includes balance equations stating that the output of each sector in current prices must be equal to the value of deliveries of this output to all nine industrial sectors and to final demand. These equations assure that differences between prices received by producers and prices paid by consumers reflect excise and sales taxes paid on the value of each product.

Our econometric model of interindustry transactions includes models of producer behavior for each industrial group included in the model.[3] Producer behavior in each industrial sector can be characterized by a system of technical coefficients, giving primary and intermediate inputs per unit of output of the sector. The model of producer behavior gives the technical coefficients as functions of the prices of output and of primary and intermediate input. For each sector the technical coefficients as functions of the prices are generated from the price possibility frontier, giving the minimum price of output of the sector attainable for given prices of primary and intermediate inputs and for a given level of productivity of the sector. The minimum price of output depends on the technological possibilities for substitution among primary and intermediate inputs, including the substitution between energy and non-energy inputs and the substitution among different forms of energy. The price possibility frontier for each sector provides a representation of the technology of that sector. This representation assures that the value of output of the sector is equal to the sum of the values of all primary and intermediate inputs into the sector.

Finally, our econometric model of interindustry transactions includes a model of consumer behavior that allocates personal consumption expenditures among the commodity groups included in final demand.[4] Consumer behavior can be characterized by a system of quantities purchased per capita. The model of consumer behavior gives the quantities purchased as functions of total personal consumption expenditures per capita, prices of the products of the nine industrial sectors, and prices of capital services and non-competitive imports. The quantities purchased as functions of total expenditure and the prices can be generated from the indirect utility function, giving the maximum level of utility attainable for given total expenditure and given prices. The maximum level of utility depends on the substitutability of alternative goods and services in consumption, so that the indirect utility function provides a representation of consumer preferences. This representation assures that the sum of the values of all quantities purchased is equal to total personal consumption expenditures.

Starting with prices of primary inputs -- capital services, labor services, and imports -- and levels of productivity in each of the nine industrial sectors, the prices of both energy and non-energy products are determined by the nine price possibility frontiers. With prices of primary inputs and prices of energy and non-energy products determined from our model of production, we can generate the matrix of technical coefficients, giving primary and intermediate inputs per unit of the output of each of the nine industrial sectors. Similarly, with total personal consumption expenditures, the prices of capital services and non-competitive imports, and the prices of energy and non-energy products, we can generate the quantities purchased per capita of the products of the nine industrial sectors, capital services, and non-competitive imports. Given the level of population, we can convert these quantities per capita to quantities of personal consumption expenditures as a component of final demand. To obtain final demand for the output of each of the nine industrial sectors we add personal consumption expenditures to gross private domestic investment, government purchases of goods and services, and exports.

From the quantities of final demand for the output of each of the nine industrial sectors and the matrix of technical coefficients, providing intermediate input per unit of output of each sector, we can determine the quantities of output of both energy and non-energy sectors. We can also determine the distribution of the output of each sector between intermediate and final demand and the distribution of intermediate demand among intermediate inputs to each of the nine industrial sectors. The output of energy sectors and its distribution can be expressed in constant prices, physical units such as tons of coal or barrels of petroleum, or energy units such as Btu's. From the matrix of technical coefficients of primary input per unit of output, we can determine the quantities of primary input into each sector. Finally, given the nine industrial prices and the prices of primary inputs, we can express the flow of primary input, interindustry transactions, and final demand in current prices. We can generate the complete system of interindustry accounts in current and constant prices from the prices of primary inputs, the levels of productivity in each interindustry sector, total personal consumption expenditures, and the quantities of final demand for the output of each sector for investment, government purchases, and exports.[5]

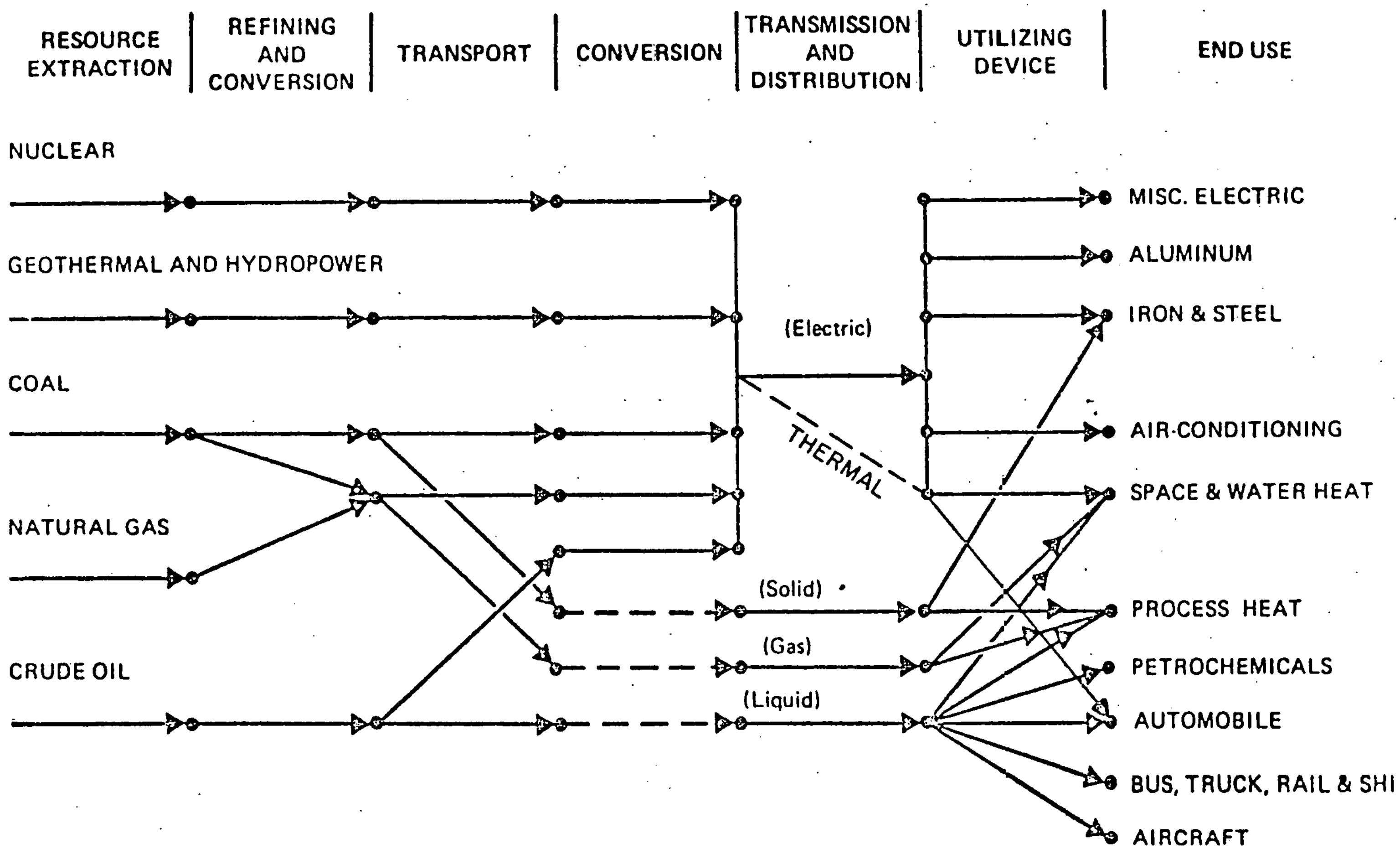
The second component of our model for the analysis of energy policy is a process analysis model of the energy sector, developed at the Brookhaven

National Laboratory (1973). This model is based on the Reference Energy System presented in Figure 3. This description of the U.S. energy system provides a complete physical representation of the technologies, energy flows, and conversion efficiencies from extraction of primary energy sources through refining and various stages of conversion from one energy form to another, and through transportation, distribution, and storage of energy.[6] In the Reference Energy System energy supplies such as nuclear fuels, fossil fuels, and hydropower are allocated to energy demands defined on a functional basis such as space heating, industrial process heat, and automotive transportation. The characteristics of utilizing technologies, which are important in the identification of conservation and fuel substitution options, are included at the same level of detail as supply technologies. The allocation of energy resources to specific demands depends on the energy technologies that are available for the production, transportation, distribution, and storage of energy and on the cost and efficiency of these technologies. The allocations may be determined by a judgemental or optimization approach. Conversion losses are represented by the efficiency of each conversion process in physical terms. In the Reference Energy System all energy flows are measured in British thermal units (Btu's).

In the Reference Energy System energy supplies and demands are linked by energy conversion processes, such as steam generation of electricity from coal. This process converts a primary energy supply, coal, into an intermediate form of energy, electricity. Electricity can be used to satisfy demands for a variety of energy products, such as base, intermediate, and peak load electricity, space heat, air conditioning, and water heat. For each process we can specify the efficiency of conversion of primary energy supplies into intermediate forms of energy and the efficiency of conversion of the intermediate

Figure 3.

REFERENCE ENERGY SYSTEM



forms into final energy services or products. For the coal steam electric process the conversion loss from the primary to the intermediate form of energy is associated with the generation of electricity. Similarly, the conversion loss from intermediate to final form of energy is associated with transmission and distribution losses for electric energy and the conversion efficiency of the end use device. The supply efficiency for a given energy source is defined as the product of the supply efficiencies on a path from the primary resource to the intermediate form of energy. Similarly, the demand efficiency is defined as the product of the demand efficiencies on a path from the intermediate form to the final energy product.

The Brookhaven Energy System Optimization Model (BESOM) is based on the allocation of energy supplies to energy demands to minimize cost.[7] The minimization of cost can be formulated as a linear programming problem of the transportation type. Sources in the transportation problem can be identified with energy supplies; in the optimization model there are eleven types of energy supplies, including underground and strip-mined coal, domestic, shale, and imported oil, domestic and imported natural gas, and hydro electric, nuclear, geothermal, and solar energy. Uses can be identified with energy demands, including base, intermediate, and peak load electricity, low, intermediate, and high temperature thermal, ore reduction, petrochemicals, space heat (including heat pumps as well as electric resistance heat), air conditioning, and water heat, and air, truck and bus, rail and automobile transportation. Energy storage and synthetic fuels including hydrogen are also incorporated in the model.

The optimization model is designed around the Reference Energy System. Each trajectory through the system from a resource to a specific end use is represented by a single activity. The data for the model are:

1. The level of demand for energy services for energy products,

consistent with those determined in the integrated model.

2. Annual production constraints on supply of energy resources and availability constraints on new technologies.[8]

3. Characterization of energy supply and use technologies in terms of conversion efficiency, capital and operating cost, and emissions to the environment (air, water, and land).

4. Definition of objective function.[9] This can be based on annual cost, including the cost of energy resources, or on alternative objectives that include utilization of primary resources, capital requirements, environmental impact, and dependence on imports.

5. Definition of any special constraints required to reflect policies or market forces that result in departures from an unconstrained optimum.

Given these data, the optimization determines resource utilization, technology, and fuel mix employed to satisfy the energy product requirements. Activity levels are given in terms of the quantity of fuel or energy delivered from a supply trajectory to the end use.

In BESOM each energy supply-demand combination is associated with costs of extraction, refining and conversion, transportation and storage, and final utilization. Annual costs per unit of operation of an energy conversion process include both capital costs and operating costs. Capital costs are converted into annual form and are conceptually equivalent to the capital service prices that enter into the econometric model of interindustry transactions. Constraints on the supply of energy resources and the degree of implementation of new technologies are based on geological information, market surveys and engineering judgement. A version of BESOM has been developed which incorporates supply elasticities to relate annual resource production levels to the shadow prices on resources determined in the model. Each energy conversion process produces environmental pollutants as well as intermediate forms of energy. Constraints can be imposed on the level of environmental pollution as well as on the level of energy demand and supply. Capacity limitations on energy conversion processes can be included as separate constraints in the optimization model; additional constraints corresponding to balance requirements between peak and off-peak electricity generation can also be included.

The energy sector optimization model determines a set of energy conversion levels that minimizes the cost of satisfying energy product demands from energy resource supplies. The dual to this linear programming problem is to maximize the value of energy products less the value of primary energy supplies by choosing a set of energy product and energy resource shadow prices. These shadow prices assure that the value of the output of each conversion process in actual use is equal to the value of input, including the input cost of primary energy supplies and any scarcity shadow prices and costs of extraction, conversion, and transportation, just as in the econometric model of interindustry transactions. Any energy resource with a positive price is fully utilized; similarly, the demand for any energy product with a positive price is exactly satisfied. For energy products and resources with positive shadow prices, supplies and demands are balanced in both physical terms and in current prices, as in our econometric model of interindustry transactions.

The solution of the dual to the energy sector optimization model determines the shadow prices associated with energy products and energy resources. The assignment of energy supplies to energy demands through energy conversion processes determined by the model can be represented in physical terms in the Reference Energy System format. Given the prices of resources and the costs associated with energy conversion processes, BESOM also provides a complete description of the energy sector in financial terms. We can generate the resultant energy system scenario in the format of the Reference Energy System in both physical and financial terms from the costs of energy conversion processes, the availability of energy resources, the requirements for energy products, and any additional constraints associated with conversion capacities and environmental restrictions.

In appraising alternative energy research, development, and demonstration policies we first associate with each policy the resulting technology for the energy sector; changes in energy research and development policy are associated with changes in dates of commercial implementation, costs, and technical characteristics of specific energy technologies.[10] We can introduce the corresponding changes in energy technology into the Reference Energy System in two ways. First, the introduction of new technologies provides new energy conversion processes in addition to those that already exist. Accelerated research, development, and demonstration programs may make it possible to accelerate the introduction of new technologies. Second, the improvement of existing technologies may increase the efficiency of energy conversion or may reduce the costs of extraction, conversion, or transportation. More extensive research, development, and demonstration may speed the increase in efficiency or the reduction in cost. The introduction of new energy technology or the improvement of existing technology may reduce the costs associated with meeting given demands for energy products from given energy resource supplies. For any change in the technology options resulting from new policy initiatives we can assess the effects on the energy sector in both physical and financial terms, using the energy sector optimization model. We can also assess the environmental impact of the changes, using the environmental impact associated with alternative energy conversion processes.

3. Model Integration.

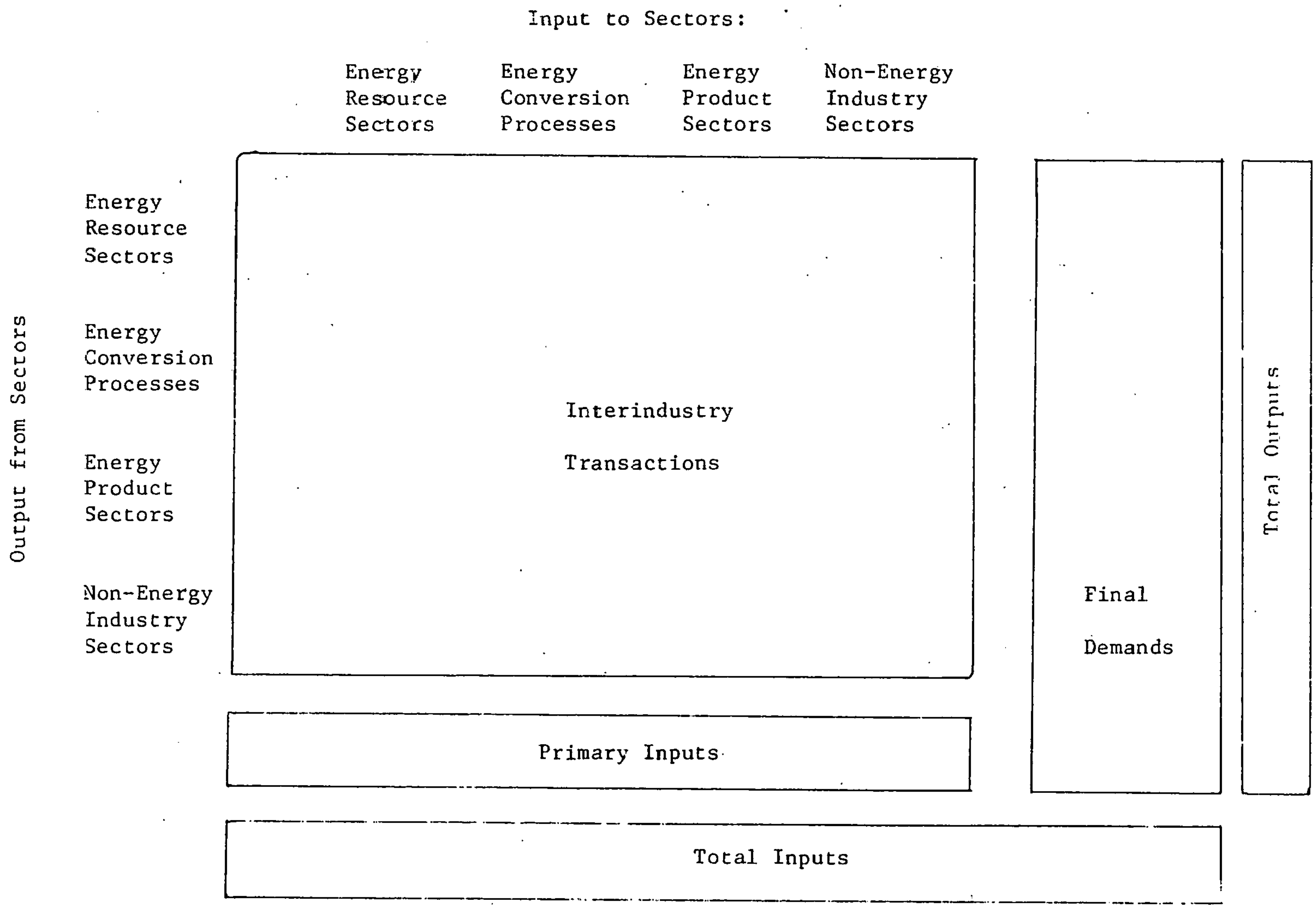
We have presented the two models approach for the analysis of energy research, development, and demonstration policy. The first is an econometric model of interindustry transactions providing a representation of the technology of the energy sector through models of producer behavior for five industrial groups that make up that sector. In addition, the econometric model provides a representation of the non-energy sector through models of producer behavior for four industrial groups making up that sector and a model of consumer behavior for the personal consumption expenditures component of final demand. The second model for the analysis of energy policy is an optimization model for the energy sector providing a much more detailed representation of the technology of that sector through the specification of characteristics of energy conversion processes linking energy resource supplies with energy resource demands. The energy sector optimization model includes existing technologies, such as steam generation of electricity from coal, and technologies that can be developed through research, development, and demonstration programs, such as the liquid metal fast breeder reactor for the generation of electricity.

Although both components of our energy policy model can be used to generate a description of the energy sector in physical and financial terms, the energy sector optimization model provides a far more detailed characterization of technology and permits the analysis of the effects of introducing new technologies. The econometric model also provides a description of the non-energy sector and generates a complete description of the U.S. economy, including flows of primary input, interindustry transactions, and final demand in current and constant prices. The energy sector optimization model is especially well suited to the assessment of the impacts of alternative research, development, and demonstration policies on the energy sector. The econometric interindustry model is well suited to the assessment of the impact of these policies on the economy as a whole. By integrating the two models we can combine the detailed characterization of technology available from the energy sector optimization model with the complete representation of the economy, including energy and non-energy sectors, available from the econometric interindustry model. This section describes the conceptual basis for the integration of the models. A preliminary version of the integrated model has been implemented and applied by Behling, Dullien, and Hudson (1976).

Our integrated model is based on an expanded system of interindustry accounts for the private domestic sector of the U.S. economy. In our expanded system of interindustry accounts the energy sector is divided into energy resource sectors, energy conversion processes, and energy product sectors. The remaining components of our original system of interindustry accounts -- interindustry transactions in non-energy products, primary inputs, and final demands -- are also included in the expanded system. The expanded system of interindustry accounts is presented in diagrammatic form in Figure 4. A complete list of the sectors included in this system of accounts is also given in Figure 4. The non-energy industry sectors of our expanded system correspond to industry groups that can be found in a conventional interindustry accounting system. Similarly, primary inputs such as capital and labor services and final demands such as personal consumption expenditures and gross private domestic investment occur in a conventional system.

To incorporate a detailed physical representation of the energy sector we have introduced categories of transactions involving energy resources,

Figure 4. Interindustry Transactions in the Integrated Model.



Energy Resource Sectors:

1. Underground Coal.
2. Strip-mined Coal.
3. Domestic Oil.
4. Shale Oil.
5. Imported Oil.
6. Domestic Natural Gas.
7. Imported Natural Gas.
8. Hydro Energy.
9. Nuclear Energy.
10. Geothermal Energy.
11. Solar Energy.

Energy Conversion Processes:

12. Coal Steam Electric.
13. Coal Steam Combined Cycle.
14. Oil Steam Electric.
15. Oil Steam Combined Cycle.
16. Gas Turbines.
17. Gas Steam Electric.
18. Total Energy Systems.
19. LWR Electric.
20. LMFBR Electric.
21. HTGR Electric.
22. Hydro Electric.
23. Geothermal Electric.
24. Solar Electric.
25. Pumped Storage.
26. Synthetic Gas from Oil.
27. Synthetic Gas from Coal.
28. Electrolytic Hydrogen.
29. Methanol.
30. Hydrogen from Coal.
31. Synthetic Oil from Coal.

Secondary Energy Forms and Energy Product Sectors:

32. Base Load Miscellaneous Electric.
33. Intermediate Load Miscellaneous Electric.
34. Peak Load Miscellaneous Electric.
35. Storage and Synthetic Fuel.
36. Miscellaneous Thermal, Low Temperature.
37. Miscellaneous Thermal, Intermediate Temperature.
38. Miscellaneous Thermal, High Temperature.
39. Ore Reduction (Iron).
40. Petrochemicals.
41. Space Heat.
42. Air Conditioning.
43. Water Heat.
44. Air Transport.
45. Truck, Bus.
46. Rail.
47. Automobile.

Non-Energy Industry Sectors:

48. Agriculture, Nonfuel Mining, and Construction.
49. Manufacturing, Excluding Petroleum Refining.
50. Transportation.
51. Communications, Trade, and Services.

Primary Inputs:

52. Imports.
53. Capital Services.
54. Labor Services.

Final Demands:

55. Personal Consumption Expenditures.
56. Gross Private Domestic Investment.
57. Government Purchases of Goods and Services.
58. Exports.

energy conversion processes, and energy products that do not correspond to industry sectors in a conventional interindustry accounting system. The activities of the five industry groups comprising the energy sector in our econometric model are allocated among energy resources, energy conversion processes, and energy products in the integrated model. For example, the electric utility sector in the original system converts fossil fuels and other energy resources into base load, intermediate load, and peak load electricity and into other energy products such as space heat and air conditioning. In our integrated model energy flows are represented in energy units (Btu's) as in the Reference Energy System. Non-energy flows are represented in constant dollars, as in our econometric model of interindustry transactions. Given a set of energy product and energy resource prices and prices for non-energy products and primary inputs, our expanded system of interindustry accounts can also be represented in current prices.

In the integrated model energy resources are delivered to energy conversion processes and to final demand for inventory accumulation and for exports. Energy resources are also used in the production of energy resources; for example, coal is used as a fuel in the coal mining industry. However, energy resources are not delivered to energy products, to non-energy sectors of our integrated model, to personal consumption expenditures, or to government purchases of goods and services. The corresponding entries in our expanded system of interindustry accounts are equal to zero. Similarly, in the integrated model energy conversion processes deliver their output to energy product categories such as miscellaneous electric demand and rail transportation. The outputs of energy conversion processes are used in energy conversion; for example, production and distribution of electricity require electric energy. There are no direct deliveries to energy resource sectors, to non-energy sectors, or to final demands in our integrated model; the corresponding interindustry accounting entries are zero. Finally, energy products are delivered to non-energy industrial sectors and to final demand. There are no deliveries of energy products to energy resource, energy conversion, or energy product sectors, so that the corresponding interindustry accounting transactions are zero.

All final demands for energy in our integrated model, except for inventory accumulation and exports of energy resources, are supplied by deliveries of energy products. Similarly, all demands for energy by non-energy producing sectors are supplied by deliveries of energy products. The first step in the construction of our expanded system of interindustry accounts is to disaggregate flows of energy from the five industry groups that make up the energy sector in our econometric interindustry model. Flows from these groups to the four non-energy industry groups and the four categories of final demand are distributed among energy product categories in our integrated model on the basis of historical data. For example, deliveries from the electric utility sector to non-energy industry groups and final demand categories are divided among base load, intermediate load, and peak load miscellaneous electric and among the other energy products that can be supplied by electric energy. Not all energy products can be supplied by means of electricity. Miscellaneous thermal, air transportation, and truck and bus transportation are examples of energy products supplied by non-electric energy sectors in our econometric model of interindustry transactions.

The energy sectors in our integrated model employ inputs of capital and labor services, non-energy intermediate goods, and energy. The energy inputs are represented in the same way as in the Reference Energy System. Energy resources are delivered to energy conversion processes and energy products receive deliveries from energy conversion processes. Inputs of labor services and non-energy intermediate goods are components of operating cost in the objective function of the energy sector optimization model. To obtain total operating cost in current prices we evaluate labor services and non-energy intermediate goods given a system of prices for primary inputs and non-energy products. Similarly, inputs of capital services are a component of capital cost in the objective function of the optimization model. Capital cost in current prices is expressed in annual form. The second step in construction of our expanded system of interindustry accounts is to disaggregate flows of non-energy products and primary inputs in the energy sector optimization model. For each energy resource, energy conversion process, and energy product these flows must be distributed among the four non-energy industry groups, capital services, and labor services.

Our integrated model is based on an expanded system of accounts for interindustry transactions. The integrated model includes balance equations between supply and demand for products of each of the fifty-one sectors included in the model -- eleven energy resource sectors, twenty energy conversion processes, sixteen energy products, and four non-energy industrial sectors. The model incorporates a process analysis representation of the technology of the energy sectors of the model and an econometric representation of the technology of the non-energy industry groups. It also incorporates an econometric model for personal consumption expenditures. The integrated model can be used to generate a complete system of interindustry accounts in current and constant prices. The integrated model can also be used to generate energy flows in physical terms for the forty-seven categories of energy included in the model.

A flow chart of the integrated model is presented in Figure 5. The first step in solving the model is to solve the econometric model of interindustry transactions and the energy sector optimization model separately. From these initial solutions we determine the final demands for the non-energy industrial sectors and the demands for the five energy industrial sectors in the econometric model. Using a fixed distribution of final demands for the products of the five energy sectors to energy product categories, we can determine final demands for sixteen energy products and for inventory accumulation and exports of energy resources. We obtain technical coefficients for the four non-energy industrial sectors from the econometric model. Using a fixed distribution of intermediate demands for the products of the five energy sectors to energy product categories, we allocate demands for energy by the four non-energy sectors among the sixteen energy products. We obtain technical coefficients for the forty-seven energy sectors of the integrated model from the energy sector optimization model. Given the technical coefficients and the final demands, we can determine levels of output for all fifty-one sectors of our integrated model. Given the prices of primary inputs and non-energy industrial products from the econometric model, energy resource prices, energy conversion costs, and energy product prices from the energy sector optimization model, we can convert the array of interindustry transactions, final demands, and primary inputs into current prices.

The second step in solving the integrated model is to generate input data for the energy sector optimization model. The eleven energy resource supplies correspond to levels of energy resource output in the integrated model. The sixteen energy product demands correspond to levels of energy product output in the model. Unit conversion costs for the twenty energy

Figure 5. Flow Chart of the Integrated Model.

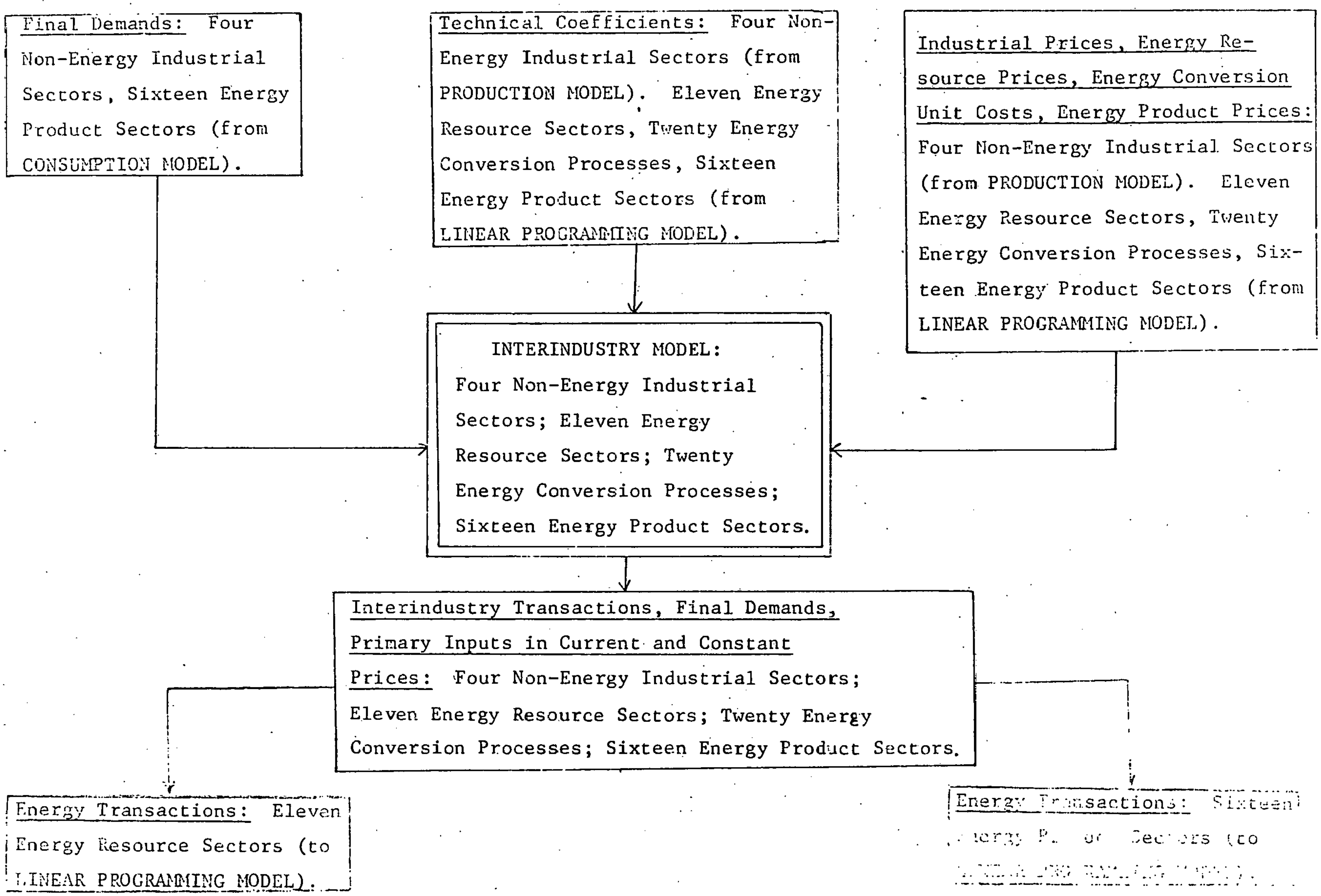


Figure 5. Flow Chart of the Integrated Model (continued).

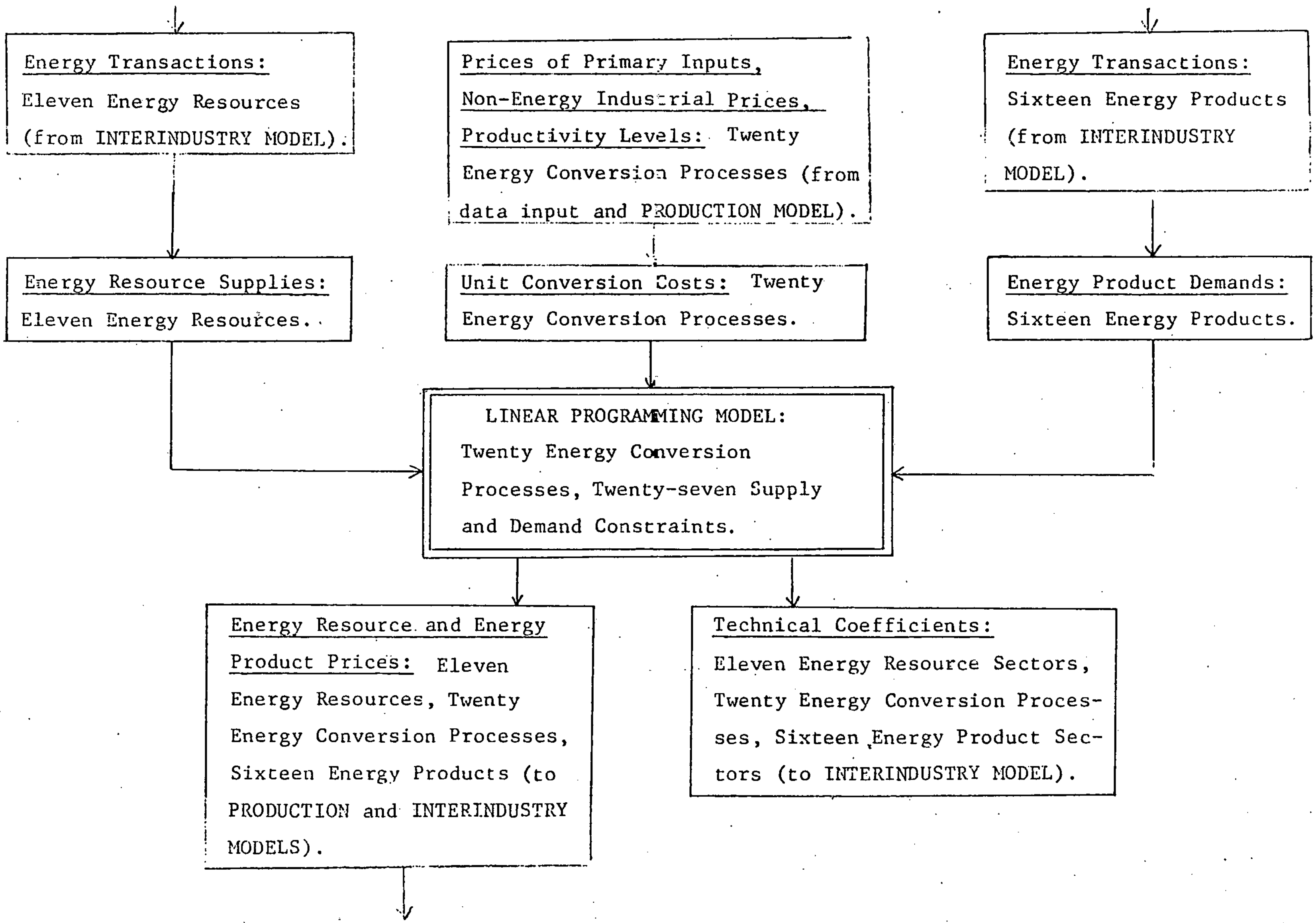
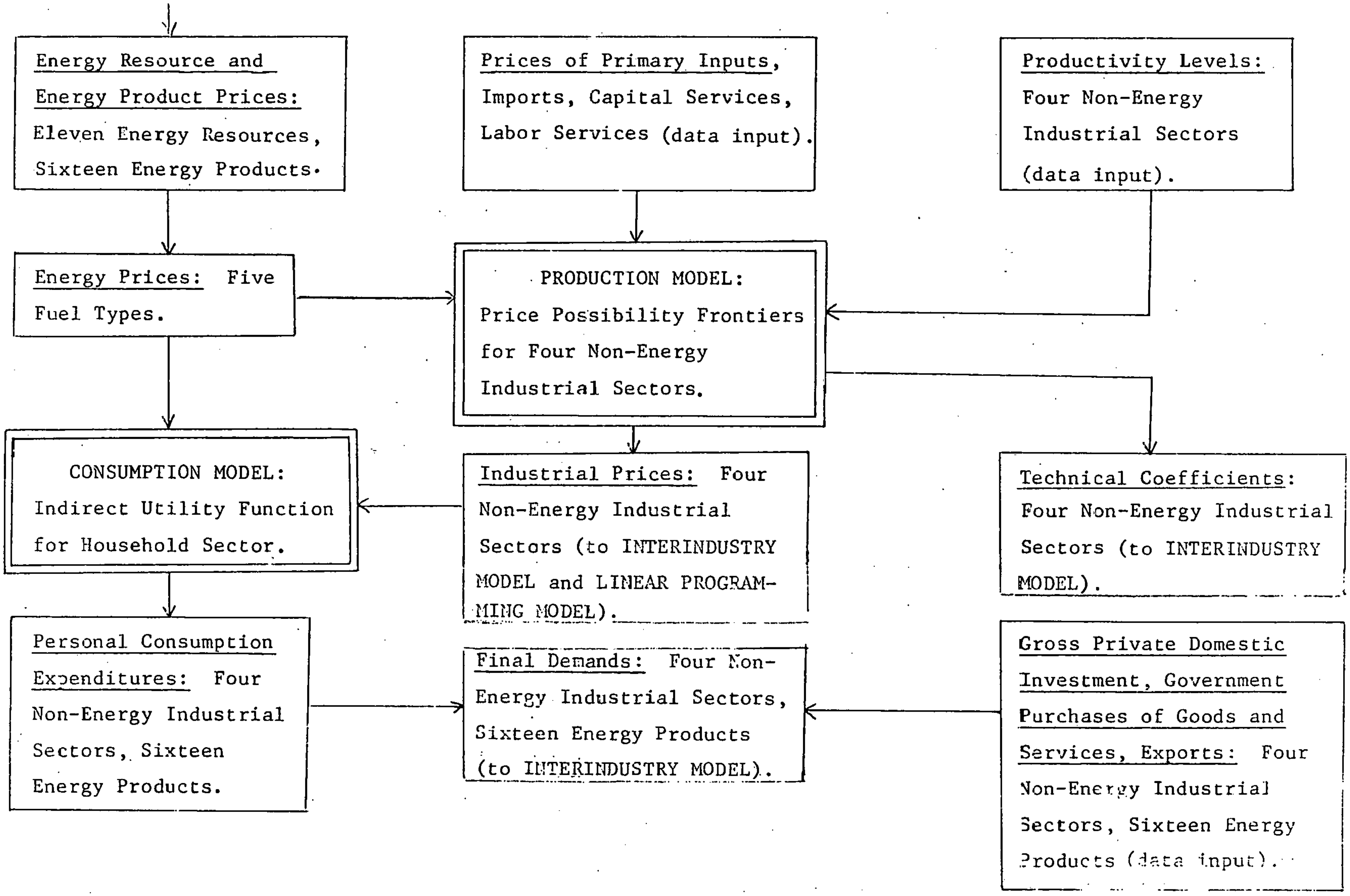


Figure 5. Flow Chart of the Integrated Model (concluded).



conversion processes are the sums of unit operating and capital costs for the conversion processes of the model. Operating costs include costs of labor services and costs of intermediate goods employed in the conversion processes.[11] Capital costs correspond to costs of capital services in the model. These data define a linear programming model that is identical to the energy sector optimization model. Given the unit costs, the energy product demands, and the energy resource supplies, the energy sector optimization model generates cost minimizing levels for the energy conversion processes and value maximizing prices associated with energy supplies and demands.

The third step in solving the integrated model is to determine prices for products of each of the five energy sectors that appear in the econometric interindustry model. Prices of domestic petroleum, natural gas, and coal correspond to energy resource prices from the energy sector optimization model. The prices of gas delivered by gas utilities, electricity, and refined petroleum products are determined as a weighted average of the corresponding energy product prices. The weights are based on the proportions of deliveries of each fuel to each energy product in the total of all deliveries of the fuel. Given the prices of the products of the five energy sectors that appear in the econometric model, the prices of primary inputs, and the levels of productivity in each of the four non-energy industrial sectors, we can determine prices for the products of the four non-energy sectors from the four price possibility frontiers for these sectors from the econometric model. From energy and non-energy prices and the prices of primary inputs, we can generate the technical coefficients for the non-energy industrial sectors of the integrated model. On the basis of these prices we can allocate total personal consumption expenditures among the products of the nine sectors of the econometric model and primary inputs.

We have outlined three steps in the solution of the integrated model. At the completion of these steps we have generated a new set of data to initiate the process of solution. We repeat the sequence of three steps until the data employed to initiate the process are generated as a solution of the integrated model. The integrated model includes technical coefficients for the energy sector from the energy sector optimization model, technical coefficients for the non-energy sector from the production models for the four non-energy industrial sectors from the econometric interindustry model, and final demands for energy and non-energy products from the econometric interindustry model, allocated among the energy products of the energy sector optimization model. The expanded interindustry model assures that supplies and demands are balanced for energy resources, energy conversion processes, energy products, and non-energy products.

To summarize: a solution of the integrated model consists of a solution of the expanded interindustry model for which the following conditions hold:

1. The energy conversion levels minimize cost for the corresponding levels of energy demands and supplies, and the corresponding unit costs of the energy conversion processes.

2. The prices of energy products and energy resources maximize the value of the products less the value of the resources.

3. The prices of the five fuel types in the econometric interindustry model are generated by dual solution of the LP model.

4. The prices of the four non-energy products are consistent with the energy product and fuel prices and the exogenously given prices of primary inputs.

5. The unit costs of the energy conversion processes are consistent with non-energy product prices and the given prices of primary inputs.

6. The technical coefficients for the energy sectors are those associated with the cost minimizing solutions of the energy sector optimization model; the technical coefficients for the non-energy sectors are those associated with the prices for primary inputs, the four non-energy products, and the five fuel types.

7. The final demands for energy and non-energy products are those associated with the prices for these products.

Under these conditions the value of the output of each sector of the expanded interindustry model is equal to the value of the input of that sector.

4. Application.

We next present an application of the preliminary version of the model to the analysis of energy research, development, and demonstration policy.[12] Our first step is to establish a Base Case, representing a projection of the U.S. economy and the energy sector through 1985, that meets the following specifications:

1. Real gross national product will grow at four percent per year from 1975 to 1985.

2. Energy prices will grow relative to the implicit deflator of the gross national product at 1.3 percent per year over the same period.

3. Energy supplies for 1985 are similar to the "calibration case" presented in 1976 National Energy Outlook (1976), as modified for the purposes of this analysis.

4. The availability of new energy technology for 1985 is given by the "combination scenario," in A National Plan for Energy Research, Development and Demonstration (1975).

Under these assumptions imports rise for 8.6 percent of total U.S. energy supply in 1967 to 18.4 percent of total supply in 1985.

The dramatic increase in the proportion of energy resource supplies that must be imported under the Base Case assumptions for 1985 suggests that energy policy may have to be modified in order to meet national security objectives. Accordingly, we have examined the implications of a reduction of imports from 18.4 percent of total energy supply in 1985 to no more than ten percent of total supply in that year. This objective requires the introduction of a tariff on imported petroleum at the rate of 51.8 percent; we have also introduced taxes on domestic supplies of oil and gas so as to leave the prices received by domestic suppliers unchanged. Energy product and conversion levels under the Base Case assumptions and under our Alternative Case for 1985 are presented in Table 1. The results of the proposed change in policy are presented in Table 2. Energy prices rise by an average of 11.6 percent with the greatest increase in the price of refined petroleum products. New technologies such as oil from shale, direct use of solar energy, generation of electricity from geothermal sources, and coal gasification and liquefaction are introduced in greater quantities under the alternative energy policy. In addition there is greater reliance on nuclear energy through use of both light water reactors and high temperature gas-cooled reactors for generation of electricity. Finally, electric automobiles are introduced on a modest scale in order to conserve gasoline.

The reduction in oil and gas imports resulting from the energy policy underlying our Alternative Case for 1985 is analyzed in Table 3. Of the total

Table 1. Energy Products and Conversion Levels, Base Case and Alternative Case 1985 (quadrillion Btu's).

	Base Case	Alternative Case	Percentage Change
1. Energy Products			
Air Conditioning	2.14	2.01	-6
Private Ground Transportation	3.04	2.75	-10
Air Transportation	0.85	0.78	-8
Truck, Bus, & Diesel RR	0.95	0.84	-12
Space Heat	12.73	11.96	-6
Water Heat	1.79	1.67	-7
Process Heat	10.91	10.64	-2
Misc. Electric (Incl. Elec. RR)	5.39	5.09	-6
Coke for Iron Production	1.64	1.56	-5
Petrochemicals	4.83	4.70	-3
2. Electricity Generation			
Coal Steam	10.71	11.53	+8
Coal Steam Comb. Cycle	0.00	0.00	0
Solvent Refined Coal Steam	0.00	0.00	0
Oil Steam	3.71	2.21	-40
Gas Turbine	1.57	1.73	+10
Gas Steam	4.39	2.70	-38
Total Energy Systems	0.00	0.02	--
LWR	9.55	10.51	+10
HTGR	0.00	0.25	--
Hydroelectric	3.38	3.38	0
Geothermal	0.69	1.66	+141
Solar	0.00	0.00	0
Total Electricity Inputs	34.00	34.00	0
Other Inputs	66.00	62.70	-5

Source: Behling, Dullien, Hudson (1976), Table V.4, page 84; Table V.8, page 96.

Table 2. Alternative Case 1985.

1. Energy Prices (Percentage Change from Base Case 1985).

Coal	0.0
Refined petroleum	35.3
Refined gas	-4.6
Electricity	2.4
Energy	11.6

2. New Technology (Change from Base Case 1985 in quadrillion Btu's).

Oil Shale	1.00
Direct Solar	0.20
Geothermal Electric	0.97
Coal Gasification and Liquefaction	1.42
LWR	0.96
HTGR	0.25
Electric Car	0.09

Source: Behling, Dullien, and Hudson (1976), Table V.3, page 81; Table V.1, page 77.

Table 3. Reduction in Oil and Gas Imports, Alternative Case 1985 (quadrillion Btu's).

1. Reduced Demand	3.30
2. Increased Supplies	
Oil Shale	1.00
Direct Solar	0.20
Geothermal Electric	0.97
3. Substitution	
Coal Gasification and Liquefaction	1.42
LWR	0.96
HTGR	0.25
Electric Car	0.09
4. Total Reduction	8.42

Source: Behling, Dullien, Hudson (1976), Table V.2, page 78.

reduction in imports of 8.42 quadrillion Btu's in 1985, reduced demand accounts for 3.30 quadrillion Btu's; increased supplies account for an additional 2.17 quadrillion Btu's; the substitution of alternative forms of energy for oil and gas accounts for the remaining 2.72 quadrillion Btu's of import reduction. We recall that domestic supplies of oil and gas remain unchanged under the assumptions of our Alternative Case. The economic impact of the Alternative Case for 1985 is analyzed in Table 4. Higher prices of imported oil result in higher prices for the output of the agricultural, manufacturing, transportation, and service sectors of the U.S. economy with the greatest increase in transportation prices. In Table 4 we also present the resulting changes in technical coefficients for each of the four non-energy sectors and changes in the composition of final demand and total output for these sectors and for the energy sector as a whole.

5. Conclusion.

We have presented an assessment of the impact of energy research, development, and demonstration policies in combination with tax and tariff policies to reduce imports of energy resources for the year 1985. A complete evaluation of alternative energy policies requires assessments for a wider range of policies over a longer period of time. In addition to the impact of energy policy on the structure of the energy sector and the level and composition of overall economic activity, assessments must also be made of the impact on levels of well-being, life styles, and environmental pollution in the United States; international repercussions of alternative policies must also be considered. These assessments must be combined into an overall evaluation of energy policy.[13]

The application of the preliminary version of the model for the analysis

Table 4. Economic Impact, Alternative Case 1985.

	Base Case	Alternative Case	Percentage Change
1. Non-Energy Prices (Percentage Change from Base Case 1985).			
Agriculture			1.10
Manufacturing			0.62
Transportation			1.33
Services			0.26
2. Technical Coefficients			
Agriculture			
Capital	0.1755	0.1753	
Labor	0 2515	0.2542	
Energy	0.0148	0.0125	
Non-Energy	0.5582	0.5580	
Manufacturing			
Capital	0.1143	0.1140	
Labor	0.2959	0.2977	
Energy	0.0194	0.0189	
Non-Energy	0.5705	0.5694	
Transportation			
Capital	0.1831	0.1814	
Labor	0.4074	0.4082	
Energy	0.0390	0.0344	
Non-Energy	0.3706	0.3761	
Services			
Capital	0.3197	0.3201	
Labor	0.4025	0.4036	
Energy	0.0166	0.0161	
Non-Energy	0.2612	0.2603	
3. Final Demand (Percentage Composition).			
Agriculture	11.66	11.62	
Manufacturing	33.58	33.61	
Transportation	2.48	2.46	
Services	49.19	49.41	
Energy	3.09	2.91	
4. Output (Percentage Composition).			
Agriculture	11.94	11.91	
Manufacturing	38.40	38.44	
Transportation	40.44	40.78	
Energy	4.73	4.43	

Source: Behling, Dullien, Hudson (1976), Table V.14, page 110; Table V.17, page 118; Table V.15, page 111; Table V.16, page 115.

of energy research, development, and demonstration policy involves the creation of Base Case projections for the U.S. economy for additional years along the lines of our Base Case for 1985. The assessment of alternative energy policies requires the development of Alternative Case projections for each policy. Our model can be used to analyze the impact of energy policy on the energy sector and on overall economic activity. In addition, the energy system optimization model and other closely related models can be used to assess the environmental impact of alternative energy policies, to estimate capital requirements associated with the implementation of new technologies, and to evaluate the effect of changes in energy prices on the domestic supply of primary energy resources such as uranium, coal, oil, and gas.[14]

While the successful integration of process analysis and econometric models of energy policy is an important step in the development of a framework for the evaluation of energy policy, we must emphasize the limitations of our current approach. A fully satisfactory data base requires the development of interindustry transactions accounts for energy flows in physical terms as well as current and constant prices. It would be very useful to incorporate these accounts into the U.S. national income and product accounts on an annual basis. It would also be useful to disaggregate the non-energy sectors of our model and to extend our modeling effort to incorporate primary factor input supplies and supplies of primary energy resources. Finally, additional research is required on the most efficient techniques for solution of our model.

Ultimately, projections for different years over a planning horizon could be developed within a dynamic version of our integrated process analysis and econometric model. In a dynamic model capital requirements and investment costs, together with the prices of capital services and labor services, would be generated endogenously by incorporating the supply of primary factors of production along with the demands included in our existing framework. Such a dynamic model could be extended to encompass the development of reserves of primary energy resources, production from reserves, and the pricing of current supplies of these resources for each period of time. Research is now under way that will enable us to extend our existing model in the direction of a dynamic model for the assessment of alternative energy policies.[15]

Our objective has been to present a model that integrates a process analysis model of the energy sector with an econometric model of interindustry transactions for application to policy analyses where the technological component is significant. We have illustrated the use of this model for assessment of the impact of energy policy. We have not attempted a comprehensive evaluation of alternative energy policies in order to focus on the methodology we have developed for model integration. Integration of process analysis and econometric models, using an extended accounting framework for interindustry transactions, has proved to be feasible. A great deal of additional research will be required in order to develop the most appropriate framework for evaluation of alternative energy policies.

Footnotes

1. The data are described in more detail in a report by Jack Faucett Associates (1973). Interindustry accounts for the year 1967 have been compiled for a more detailed industry breakdown by Bullard and Herendeen (1973a-b). The corresponding interindustry model has been linked to the Brookhaven Energy System Optimization Model discussed below by Hoffman, Palmedo, Marcuse, and Goldberg (1973) and by Behling, Marcuse, Swift and Tessmer (1975). Energy flows for six years have been compiled for the Federal Energy Administration by Jack Faucett Associates (1975).

2. The model of interindustry transactions is described by Hudson and Jorgenson (1974a), especially pp. 467-474.

3. The model of producer behavior is described by Berndt and Jorgenson (1973). See also: Christensen, Jorgenson and Lau (1973) and Berndt and Wood (1976).

4. The model of consumer behavior is described by Jorgenson (1975). See also: Christensen, Jorgenson and Lau (1975) and Jorgenson and Lau (1975).

5. Applications of the econometric model to policy analysis are given by Hudson and Jorgenson (1974 a-c, 1975 a-b) and Jorgenson and Wright (1975).

6. The Reference Energy System is described in Beller et al. (1975).

7. The Brookhaven Energy System Optimization model is described by Hoffman (1973) and Cherniavsky (1974).

8. The constraints of the optimization model are described by Cherniavsky (1974), pp. 9-18.

9. The objective function of the optimization model is described by Cherniavsky (1974), especially pp. 18-23.

10. Methodology for application of the optimization model for assessment of alternative energy research, development, and demonstration policies is described by Hoffman and Cherniavsky (1974) and Cherniavsky (1975). This methodology was applied in a series of twelve scenarios for 1985 and 2000 in A National Plan for Energy Research, Development, and Demonstration (1975).

11. This link between prices and costs has not been included in the initial implementation of our model. Research is now underway to complete this linkage.

12. This application is based on the research of Behling, Dullien and Hudson (1976).

13. An overall evaluation of U.S. energy research, development, and demonstration policy, incorporating assessments of policy impacts based on our integrated econometric and systems analysis model is given by the Energy Research and Development Administration (1976).

14. For a detailed discussion of the application of our model, see Behling, Dullien, and Hudson (1976).

15. A dynamic version of the Brookhaven Energy Systems Optimization Model has been developed by Marcuse, Bodin, Cherniavsky, and Sanborn (1975). A dynamic version of our econometric interindustry model has been developed by Dullien, et al. (1976). Incorporation of models of primary resource supply into our econometric interindustry model is discussed by Bernanke and Jorgenson (1975).

Bibliography

Behling, D. J., R. Dullien and E. A. Hudson (1976), The Relationship of Energy Growth to Economic Growth Under Alternative Energy Policies, BNL 50500, Upton, New York, Brookhaven National Laboratory.

Behling, D. J., W. Marcuse, M. Swift, and R. G. Tessmer (1975), A Two-Level Iterative Model for Estimating Inter-Fuel Substitution Effects, BNL 19863, Upton, New York, Brookhaven National Laboratory.

Beller, M., ed. (1975), Sourcebook for Energy Assessment, BNL 50483, Upton, New York, Brookhaven National Laboratory.

Bernanke, B. and D. W. Jorgenson (1975), "The Integration of Energy Policy Models," Computers and Operations Research, Vol. 2, No. 3, September.

Berndt, E. R. and D. W. Jorgenson (1973), "Production Structure," Chapter 3 in D. W. Jorgenson, et al, U.S. Energy Resources and Economic Growth, Final Report to the Energy Policy Project, Washington, D.C.

Berndt, E. R. and D. O. Wood (1976), "Technology, Prices, and the Derived Demand for Energy," Review of Economics and Statistics, Vol. 58, No. 1, February, pp. 1-10.

Bullard, C. W., and R. A. Herendeen (1973a), Energy Cost of Consumption Decisions, Document 135, Center for Advanced Computation, Urbana, Illinois, University of Illinois at Urbana-Champaign.

_______, (1973b), Energy Cost of Consumer Goods 1963/67, Document 140, Center for Advanced Computation, Urbana, Illinois, University of Illinois at Urbana-Champaign.

Cherniavsky, E. A. (1974), Brookhaven Energy System Optimization Model, BNL 19569, Upton, New York, Brookhaven National Laboratory.

_______ (1975), Linear Programming and Technology Assessment, BNL 20053, Upton, New York, Brookhaven National Laboratory.

Christensen, L. R., D. W. Jorgenson and L. J. Lau (1973), "Transcendental Logarithmic Production Frontiers," Review of Economics and Statistics, Vol. 55, No. 1, February, pp. 28-45.

_______ (1975), "Transcendental Logarithmic Utility Functions," American Economic Review, Vol. 65, No. 3, June, pp. 367-383.

Dullien, R., ed. (1976), User's Guide to the DRI Long-Term Interindustry Transactions Model, Interim Report to the U.S. Department of the Interior, Washington, D.C.

Energy Research and Development Administration (1975), A National Plan for Energy Research and Development, and Demonstration: Creating Energy Choices for the Future, ERDA 48, Washington, D.C.

________(1976), A National Plan for Energy Research Development, and Demonstration: Creating Energy Choices for the Future, 1976, ERDA 76-1, Washington, D.C.

Jack Faucett Associates (1973), Data Development for the Input-Output Energy Model, Final Report to the Energy Policy Project, Washington, D.C.

________(1975), Historical Energy Flow Accounts, Final Report to the Federal Energy Administration, Washington, D.C.

Federal Energy Administration (1976), 1976 National Energy Outlook, Washington, D.C.

Hoffman, K. C. (1973),"A Unified Framework for Energy System Planning," in M. F. Searl, ed., Energy Modeling, Washington, D.C., Resources for the Future.

Hoffman, K. C. and E. A. Cherniavsky (1974), Interfuel Substitution and Technological Change, BNL 18919, Upton, New York, Brookhaven National Laboratory.

Hoffman, K. C., P. F. Palmedo, W. Marcuse, and M. D. Goldman, (1974), Coupled Energy Systems--Economic Models, BNL 19293, Upton, New York, Brookhaven National Laboratory.

Hudson, E. A. and D. W. Jorgenson (1974a), "U.S. Energy Policy and Economic Growth, 1975-2000," Bell Journal of Economics and Management Science, Vol. 5, No. 2, Autumn, pp. 461-514.

________ (1974b), "Tax Policy and Energy Use," in Committee on Finance, United States Senate, Fiscal Policy and the Energy Crisis, Washington, Ninety-Third Congress, First and Second Sessions, pp. 1681-1694.

________ (1974c), "Economic Analysis of Alternative Energy Growth Patterns," Report to the Energy Policy Project, Ford Foundation; published in David Freeman, et al., A Time to Choose, Cambridge, Ballinger, pp. 493-511.

________ (1975a), "Tax Policy and Energy Conservation," in D. W. Jorgenson, ed., Econometric Studies of U.S. Energy Policy, Amsterdam, North-Holland.

________ (1975b), "Projections of U.S. Economic Growth and Energy Demand," Report to the Edison Electric Institute, September; published in condensed form in R. W. Greenleaf, ed., Structural Change and Current Problems Facing Regulated Public Utilities, Indianapolis, Graduate School of Business, Indiana University, pp. 75-128.

Jorgenson, D. W. (1975), "Consumer Demand for Energy," Proceedings of the Workshop on Energy Demand, W. D. Nordhaus, ed., Laxenburg, Austria, IIASA, pp. 765-802.

Jorgenson, D. W. and L. J. Lau (1975), "The Structure of Consumer Preferences," Annals of Social and Economic Measurement, Vol. 4, No. 1, January, pp. 49-101.

Jorgenson, D. W. and B. D. Wright (1975), "The Impact of Alternative Policies to Reduce Oil Imports," Report to the Office of the Secretary, U.S. Department of the Treasury; published in Data Resources Review, Vol. 4, No. 6, June 1975.

Marcuse, W., L. Bodin, E. A. Cherniavsky and Y. Sanborn (1975), A Dynamic Time-Dependent Model for the Analysis of Alternative Energy Policies, BNL 19406, Upton, New York, Brookhaven National Laboratory.