Pacific Northwest Energy Related
Regional Assessment Program

Pacific Northwest Regional Assessment Program 1975 Annual Report

June 1976

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PACIFIC NORTHWEST REGIONAL ASSESSMENT
PROGRAM 1975 ANNUAL REPORT

June 1976

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FOREWORD

Under the sponsorship of the Division of Biomedical and Environmental Research of the Energy Research and Development Administration (ERDA), the Battelle-Pacific Northwest Laboratories is conducting a multi-year program directed towards assessing the long-term environmental, socioeconomic, and health effects of probable and possible energy related developments in the Northwest states.* The work is intended to develop a better understanding of the regional implications of national policies, technology development activities, and actions as well as those of state and regionally developed programs and policies.

This is the first of a series of annual and topical reports. This initial report covers the planning phases of the program, the approach to be taken, and is published to give interested parties an opportunity for comment and suggestions. Interactions and exchanges of information and data are encouraged. The program is intended to yield results which will be of interest and use to many organizations and agencies within the region. Specific results of the assessment activities will be covered in topical reports.

The reader is encouraged to contact the staff of the Regional Energy Assessment Program with any questions. Suggestions for directions the work should take in the future will be welcomed.

*Alaska, Idaho, Oregon, Montana, Washington, and Wyoming

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PACIFIC NORTHWEST REGIONAL ASSESSMENT PROGRAM 1975 ANNUAL REPORT

INTRODUCTION

The Pacific Northwest (comprised of the states of Alaska, Idaho, Montana, Oregon, Washington and Wyoming) can by several measures be regarded as a national "warehouse" of fossil energy resources. This condition coupled with an evolving national policy stressing utilization of fossil fuels in the near term prior to development of more advanced technologies for energy supply, could result in the imposition of major changes in the region's environmental, socioeconomic and possibly health status.

The objective of the Pacific Northwest Regional Assessment Program is to establish and exercise an integrated analytical assessment program for evaluation of these potential changes that may result from various energy development or conservation scenarios. Such scenarios may themselves result from federal development policies and programs, from regionally specific actions by the states and energy industries, or from actions taken by international factors currently importing energy resources into the region.

The majority of energy related actions characteristically have time scales measured in decades--long planning and implementing periods are involved and the life cycle of actions are several tens of years in length. Similar time scales therefore apply to the magnitude of the environmental, health, and socioeconomic consequences. The cumulative effect of the addition of small increments of stress undoubtedly extend this time scale even further.

After consideration of a variety of approaches to integrated assessment at a regional level, Battelle, Pacific Northwest Laboratories (BNWL) has concluded that dynamic simulation techniques provide the best available approach to evaluating the issues pertinent to the Northwest. As a result, the Pacific Northwest Regional Assessment Program has been structured in a framework involving ten sectors (shown in Figure 1). Each of these sectors involve their own submodels that receive information either from outside the model as exogenous inputs or from other sector submodels.

FIGURE 1. Analytical Framework of the Pacific Northwest Regional Assessment Program

As shown in Figure 1, there are three primary "driving" sectors--economics, energy and demography. The dynamic results from these sectors in turn provide the primary causes of change in "driven" sectors at the right of the figure. These sectors can also generate constraints (e.g., air quality limits) that can constrain developments. At the present time the model is being formulated to run to the year 2025.

In addition to the several sectors of the dynamic simulation model, a final task has as its main objective the identification and analysis of major institutional constraints to energy development in the Pacific Northwest region. In this study institutional is defined as the formal and/or public arrangements at all governmental levels which set the parameters within which energy development-related impacts may occur. A second and concurrent element of this task focuses on the identification and analysis of how such institutional constraints affect community, regional and state planning and impact mitigation in areas affected by energy development.

At the present time, dynamic simulation techniques that have been developed by others and appropriate to the various sectors shown in Figure 1 are being closely examined and the best available methods are being adopted and adjusted to meet the needs of the program. Current progress and plans call for completion of working submodels, incorporation of some regional data and functional relationships, and partial integration of these submodels by June 1976.

Initial application of the analytical framework will be to the interlaboratory cooperative program on the National Coal

Assessment. Additional problems for attention include: 1) the implications of phase out of imports of Canadian natural gas, 2) the long-term implications of the Pacific Northwest Hydro-Thermal Program, 3) the effect of the tentatively proposed transcontinental oil pipeline serving the northern tier states from Puget Sound, 4) the significance of possible load management techniques on electrical generation capacity requirements, and 5) the long-term regional consequences of energy centers.

The following pages provide information on the simulation framework on a sector by sector basis.

Energy--Economic Sectors

J. W. Currie, L. E. Erickson,
D. W. Fraley, T. P. Harrington

Energy resources development and conservation activities, energy economics and macroeconomic activity are the primary factors that will influence the energy related future of the Pacific Northwest. These factors (coupled with demographic considerations) will in turn determine the environmental, socioeconomic and health consequences of alternative paths of development.

Energy and economics are inextricably linked together in any effort directed toward providing a base of information and an assessment framework that can be used by decision makers and the public for analyzing candidate energy policies or actions. As a consequence, these two sectors of the overall simulation framework are presented together.

The role of modeling activity in obtaining the desired information is related in a pictorial fashion as shown in Figure 2. At the outset, information necessary to the program will be both quantitative and qualitative as well as consisting of scenarios indicating the type of problems which are to be addressed. Certain portions of the data will be utilized by the model to provide forecasts relative to given scenarios. Model results (information) are then combined with other information to provide assessments.

This task begins by describing as accurately as possible the regional

FIGURE 2. The Role of the Model to Regional Assessment

energy-economic system and formalizing this description into a computerized model. Initial efforts have dealt with the types of questions to be addressed by the model and, thus, with the identification of the most important descriptions of the energy-economic system that lend themselves to quantification. These descriptors (state variables) are being linked by time-dependent functions to form a conceptual and theoretically consistent economic framework. Empirical functional relationships and coefficient estimates from previous research will form an initial base for the model. We do not believe that a large data gathering effort is warranted until the base model structure with reasonable estimates of data and coefficients has undergone an initial round of sensitivity testing. This analysis will probably reinforce some initial

hypotheses about how the system responds to changes in parameter values. However, it is expected that at this stage, respecification of certain functional relationships and intensive data gathering effort for the initiation of more rigorous statistical analyses may be necessary in order to adequately describe the system behavior.

Role of Energy-Economic Submodel.

Figure 3 shows the general role of the energy-economic submodel (inside dashed rectangle) to the overall model. This submodel along with the demographic submodel drives the system.

In its present conceptual state the macroeconomic activity submodel (box 1, Figure 3) consists of the

FIGURE 3. Role of Energy-Economic Submodel to the General Regional Assessment Model

12 basic industries and 7 secondary industries shown in Table 1.

An important element of a successful energy model is the integration of energy related sectors with a macroeconomic model (box 1, Figure 3) to evaluate the interaction of differing energy prices with economic growth, other prices and other wages in the economy. Large macroeconomic models are usually unsuited for this task, due to their high degree of aggregation and concentration on problems of effective demand. Production technology is usually based on a constant returns-to-scale assumption. While this assumption may be suitable for processing energy for final demand, it cannot answer questions arising from the extractive nature of primary energy production, characterized by increasing marginal costs of production. Thus, in its present conceptual state, the interaction between variables is not captured. However, this aspect of the research has a top priority at the present time.

Also in the conceptual state is the process by which supplies and demands are matched (box 4, Figure 3) to generate absolute and/or relative market quantities and prices. Most large scale models have traditionally employed a mathematical optimization technique (e.g., linear programming) to determine equilibrium prices and quantities.^{1,2} Recent modeling efforts at the Stanford Research Institute³ (SRI) and MIT⁴⁻¹⁰ have employed cost minimizing behavior within an iterative framework without resorting to formal optimization techniques. According to SRI* and MIT,⁷ the major reasons for this approach were that the capital intensiveness of energy production and consumption coupled with existing and potential regulation at different levels create dynamic nonlinear system relationships that cannot be adequately handled within a linear programming framework. Thus, for the reasons stated above, it is planned that the market clearing mechanisms in the energy-economic submodel will be patterned after the MIT and SRI efforts.

* Personal Communication with E. G. Cazalet and D. Nesbitt, Stanford Research Institute, Menlo Park, CA.

TABLE 1. Tentative List of Industries for Economic Activity Submodel

	SIC Codes	Title
Basic Industries	01-09	Agriculture, Fisheries, and Forestry
	10-14	Mining
	20	Food and Kindred Products
	24	Lumber and Wood Products
	26	Paper and Allied Products
	28	Chemicals
	29	Petroleum and Coal Refining
	32	Stone, Clay, and Glass
	33	Primary Metals
	34-36	Fabricated Metals and Machinery
	37	Transportation Equipment
	21,22,23,25,27 30,31,33,39	Other Manufacturing
Secondary Service Industry	15-17	Construction
	40-42,44-47	Transportation
	48,49	Utilities
	50-59	Wholesale and Retail Trade
	60-69	Finance, Insurance, and Real Estate
	70-89	Services
	91-97,43	Government

Although the energy-economic submodel may eventually describe regional and subregional production and consumption processes and provide quantitative information on such variables as prices, quantities, incomes and employment in different sectors, the submodel will only assess the impacts of what economists refer to as "marketable" production and consumption.

The impacts of a class of products called externalities or "extra-market" products will not be assessed by the energy-economic submodel. An example of an extra-market product or externality (negative in this case) would be SO_x emissions from a coal-fired powerplant. The extra-market production will be generated by the

energy-economic submodel; however, physical impacts of these extra-market products will be described by the submodels concerned with air quality, land and water, social and psychological and bioproductivity impacts. These sectors ultimately should provide feedback information on resource quantity and quality to the energy-economic submodel which not only maintains consistency in the dynamic system but provides the capability for assessing the effects of environmental and economic policies over time. These submodels will also provide inputs to the impact evaluation submodel which will ultimately be provided by the Environmental Protection Agency - DBER project on the measurement of social costs of western energy development.

Energy Supply System. A comprehensive list of energy resource would include the following basic fuels: natural gas, coal, wood, crude oil, uranium, geothermal, tidal, wind, solar, hydro, shale oil, liquified gas and methane. Each energy resource may be treated as flowing through a series of stages to its ultimate end use as shown in Figure 4. The stages follow those given by Albers and Black¹² and are described below;

1. Exploration: the exploration for new energy resources and expenditures on technological advancement.
2. Extraction: the gathering of the energy resource and its preparation for transport to primary processing.
3. Transport 1: the moving of energy resource from the point of extraction or importation to the point of primary processing or export.
4. Trade 1: the exchange of the energy resources in the form they left the extraction stage from one economic sector to another and/or from one region or subregion to another.
5. Processing: utilization of the energy resources to produce usable products through various production processes.
6. Transport 2: the moving of processed fuel from the point of processing or importation to the point of conversion or export.
7. Trade 2: (also most of box 4, Figure 3) the exchange of processed fuels from one economic sector to another and/or from one region to subregion or another.
8. Conversion: the conversion of primary fuels to their consumption form and the technological conversions necessary to accommodate the use of new fuels.
9. Distribution: the distribution of the consumable fuels to their end points of consumption.
10. Consumption: (also box 3, Figure 3) the final consumption of consumable energy products by society.

Energy Conversion. The electric conversion submodel is currently based upon a FORTRAN version of Andrew Ford's "Dynamic Model of the United States Electric Utility Industry, 1950-2010."¹² We have elected to base our simulation in FORTRAN because it is the most well-known computer language and it is readily available on most machines. At this point, the conversion of Ford's DYNAMO-based simulation is reasonably complete. Data is being acquired to regionalize the model.

While Ford's model is for the electric conversion stage, it exemplifies the characteristics of the conversion stage of the energy network (box 8, Figure 4). The model may be used to show the behavior of such factors as electricity price, generating reserve margin, and the average rate of return on investments in response to other state variables.

Figure 5 provides an overview of the key factors utilized and determined by the model; as is shown, the demand for electricity is determined exogenously to this sector of the energy-economic model. This demand in turn drives electricity production

FIGURE 4. The Stages of Energy Flow in the Energy-Economic Model

and the construction of new generation capacity. As can be seen from Figure 5, cost calculations are made comparing fossil and nuclear generation, augmented with expected regulatory constraints, and new construction is determined by a capacity addition computation.

Present activities are directed toward adding the linkages to the model which are characterized by Figure 4 for the overall energy network. In addition, the first round of data necessary to embody the Northwest region's unique characteristics is being collected to drive the model. Specific changes may be expected in order to effect a regionalization of the model.

Present plans call for the energy-economic submodels to be formalized early in 1976 using best estimates for parameters, coefficients and functional relationships. Integration within the general systems model is planned for completion in June 1976.

Energy Consumption. The last two stages of the energy network are the

distribution and final consumption stages. The distribution stage distributes the consumable energy products to their points of consumption, or to the regional boundary if the energy is exported. For the purposes of the energy economics submodel, these end use sectors (box 10, Figure 4 and box 3, Figure 3) are, at the present time, as listed below:

1. Residential
2. Industrial
3. Commercial and Government
4. Transportation
5. Agricultural
6. Other

The residential consumption sector, for example, focuses on the household where the primary causal factor will be the number of households, which is provided by the demographic submodel. The household energy demand is also dependent upon a number of other demographic, economic and technical factors. These factors include the type of home, the base appliances and secondary appliances, the annual energy use per appliance, the household income level

FIGURE 5. The Electrical Conversion Stage of the Energy-Economic Model

and the price of fuel. The calculation of annual energy consumption could then involve multiplying the total number of household units having each type of appliance by the annual energy use per appliance parameter as in the Wisconsin Energy Model.¹³ Here, four specific factors are accounted for by the specification of their attributes:

1. Type of home (urban single family, urban apartment and rural).
2. Ownership fractions for three "base appliances" (space heating, water heating and central air conditioning).
3. Ownership fractions for 14 "secondary appliances" (e.g., refrigerator, freezer, dishwasher, stove, TV, etc.).
4. Annual energy use per appliance.

The manner in which the above factors may fit into the overall structure of the residential energy consumption submodel is shown in Figure 5.6. For a given year, the

FIGURE 6. Example Residential Energy Consumption Submodel Structure

simulation could begin with the determination of a demand for new homes, including that resulting from the creation of new families and from the demolition of old homes. The next step in the sequence would be the calculation of the distribution among the three housing types. These could be determined by either past trends or may be specified by the model user according to the scenario under study. Forecasts for appliance ownership would then be combined with an appliance use model incorporating the influence of future fuel availability, prices of fuels and household incomes.

Demographic Sector J. J. Jacobsen

Energy related development activities in the relatively sparsely populated regions of the Pacific Northwest may result in significant demographic changes particularly at a subregional scale. Although demographic forecasts are routinely prepared by state and Federal agencies, few, if any, of these take into account possible subregional perturbations that may result from major energy development activities. In addition, individual demographic changes may present more significant stresses to environmental quality and the socioeconomic conditions of a region than the existence of the energy facility per se. As a result, the Pacific Northwest simulation model both drives and, in turn, is driven by the demographic sector.

The demographic sector of the model simulates the interactions among the population, the birthrate, the death rate, the net migration rate and the jobs available in the region in response to exogenous inputs and inputs from other model sectors. In turn, the demographic sector will provide other model sectors with information about the number of households, the size of households, the labor force and the age structure of the population. This information will be used to determine energy demand, water usage, land requirements, demand for services and health impacts. The major elements of the demographic sector and some of

their interactions are shown in a causal diagram* in Figure 7.

As shown by the four arrows pointing toward population, the population in a region can be determined by four factors: 1) the birthrate, 2) the death rate, 3) the labor force, and 4) the labor force participation rate.** The birth rate and death rate are initially assumed exogenous to the model and constant. As the model is refined, these assumptions may be modified. Information about the number of jobs available in the region from the economic sector is compared with the regional labor force to give the regional unemployment rate. The regional unemployment rate partially determines the regional net migration rate and the labor force participation rate.

For example, if the regional unemployment rate is relatively low, it will be easier for people to find employment and people will enter the

labor market; as a result, the regional labor force participation will be relatively high. Conversely, if the unemployment rate is high, people seeking employment will become discouraged and leave the labor market resulting in a lower labor force participation rate.

The number of people in the regional labor force (employed persons and people seeking employment) is increased or decreased by the labor force migration rate. The net migration rate is, in turn, assumed to be a function of the regional wage rate and the regional unemployment rate relative to the national wage rate--the lower the regional unemployment and the higher the regional wages, the greater number of people migrating into the region.

Figure 7 also shows the feedback loop mechanism that works to keep the regional labor force in balance with the total regional jobs. This loop is emphasized in Figure 7. If, for example, the regional unemployment rate should drop, people would tend to migrate into the region increasing the regional labor force, which in turn will bring the unemployment rate back up to a "normal or equilibrium level."

This structure is closely related to the demographic sector of a model developed by Battelle-Columbus Laboratories for the Susquehanna River Basin Utility Group.¹⁴

As presently envisioned, the population will be categorized by age and by household size. This structure is shown in Figure 8. It can be viewed as a two-dimensional array, the axis being the age of the head of the household and the household size (number of people in the household). While the exact number of categories along each dimension has not been determined, initially there will be six household size classifications (single thru four or more children) and six age classifications (0 to 18, 19 to 24, 25 to 29, 30 to 44, 45 to 64, and 65+). The movement of the population within this structure will be determined by age specific migration rates, age specific birthrates and age specific death rates.

This structure is adapted from work presently underway by the

* Causal Diagrams: The structural assumptions that make up a dynamic model may be expressed by a causal diagram. In a causal diagram, system information interactions are shown by arrows leading from each element to all other variables that might be influenced by changes in that element. The polarity of each causal influence is indicated by a + or - sign at the head of the arrow. A positive polarity means that an increase in the first element will cause an increase in the second (and a decrease will cause a decrease). A negative polarity signifies that an increase in the first element will produce a decrease in the second (and a decrease will produce an increase). Causal diagrams are rough sketches of the interacting feedback loops in the model. They do not contain enough information to permit a complete understanding of the possible modes of behavior or to analyze the model on a computer, but they do convey the general pattern of major system interactions.

** The labor force participation rate equals the ratio of the people employed or seeking employment to the total number of people able to work.

FIGURE 7. Interactions Within the Demographic Sector

FIGURE 8. Structure of the Population Within the Model

Willamette Simulation Unit at Oregon State University.¹⁵

At the present time the demographic sector model is being coded and is scheduled to be debugged using trial data from a particular region by February 1, 1976. Data requirements will then be finalized and data collected during February 1976. The sector will be linked with other model sectors during March-June 1976. A report documenting the model will be available by June.

Air Resources Sector

D. S. Renne and D. L. Elliott

The objective of the air quality sector of the Regional Assessment Program is to provide estimates of the air quality, and the information necessary to assess the effects on terrestrial environments resulting from the deposition and washout of airborne pollutants, in the Pacific Northwest due to the development of the region's energy resources. A thorough assessment of these impacts requires detailed knowledge of the strength and geographic distribution of present and future energy related emissions throughout the region, including those of the energy facilities themselves as well as secondary emissions (e.g., automotive emission) resulting from the community and transportation growth that will inevitably occur as resources are developed, and a thorough knowledge of the atmospheric transport and diffusion properties throughout the region.

The energy related pollutant emissions will be obtained as part of the output of the energy/economic sectors of the regional model. Emissions factors obtained from the literature (e.g., reference 16 and 17) will be incorporated into this model to convert the amount of fuel burned or converted in various categories (such as

electrical generation or coal conversion, transportation and space heating) and the amount of particulates released by process industries and agricultural activities into total emissions of sulfur and nitrogen oxides, particulates, trace elements, carbon monoxide and hydrocarbons. The emission inventory can be divided into two basic categories: 1) primary or point source emissions due to large fuel burning or conversion facilities such as power plants and gasification plants, and 2) secondary or area source emissions due to space heating, transportation and related industries.

A regional scale transport and diffusion model which accounts for the spatial and temporal variations in the wind field^{18,19} is being used to estimate ground level air quality conditions of present and future energy development activities. This program has the capability of calculating short-term maximum as well as long-term average pollutant concentrations. This model interpolates the mean winds between 100 and 1000 m above the ground measured every 12 hr by the National Weather Service at approximately 34 sites in the Pacific Northwest (Figure 9). Trajectories of pollutant transport are then determined from these wind fields. Standard diffusion relations are used to estimate plume dispersion. Removal processes such as dry deposition and

precipitation scavenging, and chemical transformations are incorporated into the model.

In the Pacific Northwest Region Assessment model, calculations will be made using typical annual meteorological data to develop indices of the sensitivity of a grid of receptor points to composite emissions occurring throughout the region. This matrix of sensitivity indices can then be coupled to the other sectors of the regional assessment model to calculate air quality and deposition processes for exogenously specified scenarios. The rate and cumulative amount of surface deposited pollutants will be made available to the bioproductivity sector for computation of effects over time.

To date, a preliminary investigation of transport has been made for six large existing or proposed coal-fired power plants listed in Table 2. Figure 10 shows the plume trajectories for these plants for a 4-day period in April 1974 computed

FIGURE 9. Pacific Northwest Meteorological Stations Utilized in the Interpolated Wind Fields. Additional stations off the grid are used for interpolating winds near the grid boundaries.

FIGURE 10. Plume Trajectories for Six Existing and Proposed Coal-Fired Power Plants. Trajectory calculations begin at 1600 PST on April 1, 1974.

TABLE 2. Coal-Fired Power Plants for Which Plume Trajectories were Computed

Name	Location	Megawatts
Centralia	SW Washington	1400 Existing
Boardman	NE Oregon	500+ Proposed
Pioneer	SW Idaho	1000 Proposed
Jim Bridger	SW Wyoming	2000 Existing
Wheatland	SE Wyoming	1500 Proposed
Colstrip	SE Montana	2000 Proposed

from the trajectory model. The existing wind data is influenced by large topographic features such as the Rocky Mountains, and additional analytic methods are being considered to incorporate the effect of smaller topographic features such as the Columbia Basin and Willamette Valley.

Preliminary computations of ground level concentration, deposition, and scavenging of sulfur dioxide and sulfate from several large coal-fired plants in the Pacific Northwest have also been made. Precipitation scavenging is being computed using mean monthly precipitation data extrapolated to a fine-mesh grid. Ultimately the model will be run with one year of data to obtain estimates of annual average ground level pollutant concentrations and surface deposition on a grid with 2000 "receptor points" spaced approximately 35 km apart. The emphasis for the remainder of FY 76 will be on annual average sulfur dioxide and sulfate concentrations associated with existing and planned coal-fired power plants and coal conversion facilities in the Pacific Northwest. This effort will include the development of a coal-related emission inventory for the region.

Land and Water Resource Sectors M. W. Stradley and S. J. Shupe

Future regional developments relating to energy extraction, conversion, transmission and consumption are expected to impact the land and water resources of the region. First order or direct land and water related impacts which can result from such developments are typically con-

sidered in environmental impact statements which are filed for individual projects in accordance with state and Federal statutes. While these statements provide important insights into local impacts they often do not consider the long-term systematic impacts which may arise in a particular region or subregion as a result of sequential and seemingly unrelated developments. The systems approach taken in the Pacific Northwest Regional Assessment Program is directed toward these types of phenomena. Furthermore, through interaction with other sectors such as the demographic, social/psychological, economic and energy, the feedbacks from first order land and water effects can be used to investigate second order effects which are not always obvious when traditional "mechanistic" types of impact analyses are employed.

During fiscal year 1976, efforts in the land and water resources sectors are being directed toward the Powder River area of eastern Montana and Wyoming. Geographically this area will include all or part of seven counties (Powder River, Rosebud, and Bighorn in Montana; and Campbell, Converse, Sheridan, and Johnson in Wyoming). This area has been selected for initial study due to the extensive coal-related developments which have been proposed for that area and also in anticipation of the needs of the National Coal Assessment Program being conducted jointly by the ERDA national laboratories.

Current work includes the development of land use and water resources simulation submodel sectors. The land use submodel will be designed to simulate changes in land use patterns and will be driven by demands from the economic (including agriculture), energy and demographic sectors. The proposed model, shown in terms of a causal diagram (see footnote to Demographic Sector) in Figure 11, is based on a previous land use model developed at Oregon State University.²⁰ As seen in the figure; economic, demographic and energy demands generated in other portions of the model operate on the land use submodel to cause shifts in land use patterns primarily from agricultural land to industrial and residential land. These shifts in turn affect the price of the land (both agricultural and residential)

FIGURE 11. Land Use Sector Causal Diagram

and agricultural production (computed as a function of agricultural capital and land and bioproductivity). Provisions for simulating land speculation and for directing inputs into the water resources sector are also built into the submodel. Initial model development emphasizes the land use pattern dynamics, with the economic factors being addressed in future efforts coordinated between the economics and land use sectors.

The water resources sector submodel is shown in Figure 12. As in the land use submodel, various demands from industrial, agricultural and domestic sources compete for available water as well as influence water quality for a given stream or aquifer. Initially the simulation model is being constructed to consider surface water in the main tributaries of the region. Later plans call for the integration of shallow ground water with subsequent provisions for consideration of deep ground water such as the Madison aquifer which underlies the Northern Great Plains States.

It is not presently planned to model competition for available water as a dynamic phenomenon. Rather available water for domestic, industrial and agricultural use will be allocated in a hierarchical sequence specified exogenously as part of a given scenario. Shortages of available water or adverse changes in water quality* will be monitored as part of the model output and used to identify potential problems in the water resources area which could either preclude or inhibit proposed energy related developments under a given scenario. In this sense the water resources submodel will be less interactive than the land use model and serve as a "flag" in the system. The output from the water resources submodel will be used to modify and evaluate scenarios specified external to the model.

* Water quality parameters monitored by the submodel will be dependent on the water pollution loads associated with primary energy development and secondary effects under given scenarios.

FIGURE 12. Water Resources Sector Causal Diagram

The models just described will be generic so that their application of other potential impact areas will be possible.

Social Sector M. E. Olsen

Two different models are being constructed to represent the social sector of the regional dynamic simulation model. The first termed "Energy Use Reduction Model," depicts the likely social consequences of rising prices for (or restrictions on) gasoline, heating fuel and electricity. The second, termed "Project Impact Model," depicts the probable social impacts of large-scale energy development projects (such as nuclear power plants or surface coal mining) on the surrounding area. The main reasons for differentiating these two models are that: (1) the more immediate effects of the two situations are rather different, even though some of their long-term social effects may be similar; and (2) data on the effects of reduced energy use can be aggregated from local areas to the entire region, whereas the effects

of any particular development project are largely restricted to the immediately surrounding area and cannot be aggregated to the entire region.

In the Energy Use Reduction Model, the major immediate consequences of rising energy prices and/or governmental restrictions on energy consumption are the following:

- rising cost of driving an automobile per mile
- shift in population distribution from suburbs into central cities
- movement of population from metropolitan areas to small towns and rural areas
- decline in industrial and business jobs
- price inflation.

Some likely secondary consequences of the above conditions are these:

- increase in multiple family dwellings

- decrease in housing size per person
- declining automobile utilization
- decreased purchase and use of household appliances
- lowered median family income.

In the Project Impact Model, the major immediate impacts of any large-scale development project include the following:

- creation of new jobs in the area, both associated with the project and through secondary economic growth
- population growth in the area
- changes in the socioeconomic class and/or racial composition of the area
- need for additional housing in the area
- need for additional public facilities and services of all kinds in the area.

A number of additional factors will affect a community's ability to absorb a large population influx and provide the housing and services they need, including:

- duration of the project
- current amount of unoccupied housing and under-utilized public facilities and services
- local government funding source
- availability of federal or state governmental financial assistance
- availability of employable service personnel.

As an outgrowth of these immediate and secondary effects of energy use reduction or development projects, an affected community may experience many other subsequent social impacts. Since we cannot at this time predict the precise nature of these possible long-term social impacts, we are constructing four different sets of social indicators to measure the quality of life in a local community

(which could then be aggregated to the regional level). These indicators are applicable to both the Energy Use Reduction and the Project Impact models, and could also be utilized when performing other kinds of social impact assessment. The four sets of community quality of life indicators, with their major subdivisions (but not their actual empirical measures), are listed below:

1. Community resources

- Total wealth
- Knowledge personnel
- Local government

2. Services and facilities

- Housing
- Education
- Medical care
- Public health
- Public protection
- Transportation
- Legal services
- Public welfare
- Social services
- Culture and recreation

3. Social problems

- Crime
- Juvenile delinquency
- Alcohol and drug abuse
- Mental and physical illness
- Suicide
- Family disruption
- Social isolation
- Poverty
- Educational problems
- Unemployment
- Inadequate housing
- Minority discrimination

4. Collective responses

- Participation in and actions by:
 - civic associations
 - interest associations
 - neighborhood associations
 - ad hoc citizen groups
- Organized political participation
- Development or expansion of governmental programs
- Community and regional planning
- Community conflict and collective violence

At the present time, efforts are being focused on: 1) developing an empirical measure for each separate factor in the social sector, 2) examining the existing literature to identify the presence and direction of probable linkages among these various factors, and 3) determining the crucial information flows between the social and other sectors. These three tasks are all interrelated, and hence are being conducted simultaneously. The present time schedule calls for their completion by the end of January 1976. After that, the remaining tasks will be to: 4) locate or collect the data necessary to determine the strengths of the linkages among the various factors, 5) continually revise the model in light of these empirical findings, and 6) express the model in dynamic equations. These tasks will be conducted during February-June 1976.

Psychological Sector D. H. Summers

A wide range of studies have shown that several different aspects of individual behavior are affected by certain types of changes in an individual's milieu. For that reason, energy developments which--directly or indirectly--produce changes in the immediate human milieu may also have substantial effects on behavior. Unfortunately, findings concerning the impacts of social, economic and physical environmental changes have not been systematically integrated, nor has a framework been developed which would make it possible to predict the psychological consequences of such changes.

This phase in the psychological sector of the Regional Assessment Program has focused on the identification of sources in the literature dealing with the impact of variables in the social, economic and physical environment on psychological variables such as productivity, satisfaction, levels of stress and anxiety, and attitudes towards the environment and energy-related issues, etc. Most of the literature identified to date focuses on the psychological changes produced by changes in noise levels, overcrowding, density, physical, and social arrangements in the neighborhood and community and air pollution.

On the basis of this literature review variables have been identified in each of the other model sectors which may cause or influence the types of psychological impacts associated with energy development (see Figure 13). The identification of these input variables is tentative and it is recognized that lack of further appropriate data may necessitate the elimination of some of these original variables.

The next step in this sector of the Regional Assessment Program will be to identify the type of relationship that exists between the input variables (from other sectors in this model) and psychological impacts, such as satisfaction and stress. Additionally, an attempt will be made to identify interrelationships among input variables which can affect the type of psychological impact. This step will be based on what is available from prior research efforts documented in the literature.

The third step, which will be intrasector, will be to identify relationships between psychological impacts and individual actions, using whatever data are available. The severity of the impact will presumably dictate the type of individual response or action, and individual actions will in turn affect the collective (community and government) response. The link between individual action and community response is also the link between the psychological sector and the other sectors of the model, most specifically the sociological sector.

Bioproductivity Sector R. H. Sauer

The bioproduction submodel simulates the production of agricultural products such as grains, forage, and meat. Agricultural production accounts for a significant proportion of income in the Pacific Northwest. The siting and installation of energy related facilities in the Pacific Northwest can be expected to directly or indirectly affect agricultural production through changes in land use, regional economics and distribution of by-products of the energy facility, such as SO_x or salt from cooling towers. The bioproduction

FIGURE 13. Psychological Sector Relationships

submodel thus has an intermediate position in the total model as it responds to changes in agricultural capacity and needs, and in turn provides information to the energy and economic submodels, the focal points of the total model.

Any region, whether it is the whole Pacific Northwest or a county in one of the states, cannot be expected to have a uniform environment. Annual temperatures and rainfall, for example, will vary geographically. To incorporate spacial heterogeneity, the region addressed by the model will be divided into environmental areas with uniform characteristics. For example, 5% of the region or 1000 acres could have 15 in. annual precipitation, a mean growing season temperature of 20°C, no added nitrogenous fertilizers and no toxic soil minerals. These characteristics can be static and remain the same for the duration of a model run, or can be dynamic and respond to changes in the model. Some degree of change can be expected as construction and operation of an energy facility affect supplies and demands for agricultural production.

Within each environmental area there will be a provision for more than one agricultural product. For example, in the area described above, wheat may grow on 70% of the area with beef production taking up the remainder. The total production for the region would be the sum of all beef production or wheat production in all environmental areas.

The production of each agricultural product will be estimated from relationships of the form

$$Y_i = A_{ij} (a_i X1_j + b_i X2_j \dots), \quad (1)$$

where Y is the production of product i in environmental area j ; A is the area (e.g., acres) in area j devoted to product i , a , b , . . . are coefficients for product i associated with the environmental parameters $X1$, $X2$, . . . in environmental area j . The total production of product i will be the sum of all i over j . These relationships are based on annual estimates of environment parameters and thus the model has a time step of one year.

If more detail and a mechanistic approach are needed for bioproduction in the regional model, the Ecosystems Level Model (ELM), developed by the Grasslands Biome to simulate the total grasslands ecosystem, can be used. However, the large size of ELM and the 2-day time step make it presently incompatible with the already large planned regional model with a 1-year time step. Much of the intricate detail generated in ELM would not be used in the regional model.

The bioproduction submodel will require information from the other sectors to operate. The quantity of land devoted to each product in each environmental area will be needed from the land use submodel. Similarly, the quantity of soil toxins as estimated to be deposited by the air resources submodel can be employed to calculate changes over time in bioproduction. These values should be dynamic as they will change with changing land and product values, and with urbanization.

The size and characteristics of the environmental areas will be provided with the bioproduction model. These values too should be dynamic as changes in availability of irrigation water (from the water resources sector) can make large changes in the agricultural production of an area.

The output of the bioproduction submodel will be the total production for each agricultural product in the simulated region. This information can be used by the economics submodel, for example, as input for supply and demand functions, and by the energy submodel to determine the quantity of nitrogenous fertilizer derived from natural gas or the quantity of diesel fuel needed for cultivation.

Institutional Constraints to Energy Development

M. Curry and M. Greene

The ultimate goal of this task is the analysis of institutional constraints at all governmental levels which: 1) affect energy development, 2) can be used to mitigate the occurrence of adverse impacts and 3) can be used to encourage the occurrence of positive impacts.

The first phase of this task, now nearing completion, involves identification and preliminary analysis of federal level institutional constraints for the various categories of impacts. This process has identified federal powers, agencies and legislation that may affect the nature and extent of energy development-related impacts.

This is not a large-scale effort since substantial impact-specific information exists among other staff responsible for each sector, and such specific constraints (e.g., air quality standards) will be programmed into each sector's submodel. Rather, this phase attempts to provide an overview of the relevant federal institutional constraints and analyzes the planning functions of the identified agencies and legislation to determine how these functions may help integrate adverse impacts and encourage positive impacts resulting from energy development. This phase will also analyze the specific constraints, regulations and laws to examine how such constraints interact and influence each other. The combination of such constraints may work synergistically to produce a result which is not simply the sum of the parts and this possible relationship should be identified and analyzed. This should be particularly useful in defining and analyzing constraints which affect the social, psychological, demographic and possible economic and energy sectors of the model since there may be a few formal institutional constraints focusing directly on these sectors.

The second phase of this task is to identify and analyze institutional constraints at the state and regional levels. It is anticipated that during this analysis the emphasis will be more on the planning legislation, tools and agencies available at the state and regional levels because most environmental guidelines and institutional constraints which affect specific impact sectors are found at the federal level.

Special Assessments

W. H. Swift and G. L. Wilfert

In addition to the requirement to develop a dynamic simulation framework

for the Pacific Northwest Regional Assessment Program, there are frequent needs to provide timely contributions to interlaboratory cooperative efforts (such as the National Coal Assessment) and to provide ERDA with near-term assessment information on a regionally specific basis. Further, there is a strong requirement to establish and maintain working relationships with regional and state agencies concerned with energy planning in the Pacific Northwest. This latter aspect is important in defining issues, developing common data bases and assuring that the program is responsive to regional as well as national needs. A third aspect involves the development of regional data basis compatible with the needs of the dynamic simulation program and the development of interlaboratory data base sharing and transfers.

For example, an understanding of the current "energy balance" of the states (including the relative dependencies on several energy supply forms) is essential as insight for determining the significance of possible or probable future developments. Although such balance studies are static and not predictive of either developments or effects, they do provide reference points-of-departure.

Preliminary energy balances for the Northwest states are shown in Figures 14 through 19 for calendar year 1974. These balances are derived from primary data published by the Federal Power Commission,²¹ the Edison Electric Institute,²² the U.S. Department of Transportation,²³ and the U.S. Bureau of Mines.²⁴ Although caution must be applied in using a single year's data as indicative of the present regional status, the balances do suggest a very significant dependence of the contiguous states on the imports of Canadian natural gas, a factor further illustrated in Figure 20 and Table 3. Since Canadian policies may result in major curtailment of exports in the early 1980's, the significance of this loss of basic energy supply is important in assessing what energy substitutions might possibly occur and what their impacts might be on the environment and regional economics. Quite obviously significant changes in energy balances may well occur in the near future.

In another study, the currently announced^{25,26,27} additions to electrical generating capacity in the contiguous northwest states was analyzed and is reported in Figure 21 and 22.

FIGURE 14. Preliminary Energy Balance - Alaska 1974

FIGURE 15. Preliminary Energy Balance - Idaho 1974

FIGURE 16. Preliminary Energy Balance - Oregon 1974

FIGURE 17. Preliminary Energy Balance - Montana 1974

FIGURE 18. Preliminary Energy Balance -
Washington 1974

FIGURE 19. Preliminary Energy Balance - Wyoming 1974

NOTE: SIGNED VALUES WITHIN STATES INDICATE EXCESS OF CONSUMPTION OVER PRODUCTION

FIGURE 20. Natural Gas Movements - 1974

TABLE 3. Electrical Generation Versus Natural Gas Consumption 1974 - Trillions of Btu

	Electrical Generation	Natural Gas*	Natural Gas as % of Electrical Generation
Washington	308	193	63
Oregon	122	107	88
Idaho	33	55	167
Total	463	355	77

* 60% Industrial Typical

FIGURE 21. Pacific Northwest Announced Generating Capacity

FIGURE 22. Pacific Northwest Electrical Generating Capacity - Market Share Based on Announced Plans (Washington, Oregon, Idaho, Montana, Wyoming.)

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