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DIRECT REGIONAL ENERGY/ECONOMIC MODELING
(DREEM) DESIGN

Final Report

By
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October 1979

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Urban Systems Research & Engineering, Inc.
Cambridge, Massachusetts

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MODELING (DREEM) DESIGN**

**FINAL REPORT
OCTOBER 1979**

**PETER D. HALL
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ABSTRACT

This report summarizes an investigation into the use of regional and multiregional economic models for estimating the indirect and induced impacts of federally-mandated energy policies. It includes an examination of alternative types of energy policies which can impact regional economies and the available analytical frameworks for measuring the magnitudes and spatial extents of these impacts. One such analytical system, the National Regional Impact Evaluation System (NRIES), currently operational in the Bureau of Economic Analysis (BEA), is chosen for more detailed investigation. The report summarizes the model's capabilities for addressing various energy policy issues and then demonstrates the applicability of the model in specified contexts by developing appropriate input data for three scenarios. These scenarios concern the multi-state impacts of alternative coal mining development decisions, multi-regional impacts of macroeconomic change, and the comprehensive effects of an alternative national energy supply trajectory. On the basis of this experience, the capabilities of NRIES for analyzing energy policy issues are summarized in a concluding chapter.

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1.0 Statement of the Problem

Regional growth and economic development have long been areas of concern to both policy makers responsible for the region's prosperity, and to analysts interested in identifying the relationships between economic, demographic and other phenomena. These concerns have led to intensive research into regional economies and to the development of several models capable of defining the economic consequences of changes in particular policy variables.

Recent emphasis upon energy-related matters has promoted greater demands upon the regional component of economic models, because of both the location-specific character of most energy-related phenomena and the increasing significance of impacts from energy development, distribution and consumption. These impacts, which may include those related to employment, wages, income and other measures of economic activity in the private sector, will be differentially transmitted through regional economies depending upon initial economic and demographic structure and the strengths of economic linkages between the host region and other regions.

Although the direct impacts of energy development activities can be determined to reasonable degrees of confidence, the indirect and induced impacts can only be assessed if the economic structure of the region, and the relationships of this structure to other regions is known. To varying degrees, these relationships and structures are incorporated into the regional and multiregional models to be discussed in this report.

The incorporation of energy development policies into these regional and multiregional models is in many cases difficult. Often the transformation of policy instruments into the variables of particular models is impossible or inappropriate. In other cases, a model is too aggregate (either sectorally or spatially) to recognize the interdependencies between industries or regions which give rise to the indirect or induced

impacts of interest. Furthermore, many modeling frameworks, such as "top-down" modeling methodologies overly emphasize the macroeconomic components of the economy which make them particularly insensitive for analysis of the regional impacts of any economic development projects.

The definition of the term "regional" is itself problematic as the impacts of a given energy development will vary according to the size of the region under analysis. Models appropriate for investigating impacts at the county level will usually be unable to estimate the transmission of impacts to other regions. Multiregional models, while explicitly recognizing these interregional linkages, may not be able to provide detailed estimates of impacts on the host region. Clearly, the appropriate regional detail, and thus appropriate choice of modeling framework will depend upon the types of policy issues addressed by the user.

Since in assessing energy development impacts, a wide spectrum of technology-specific policy inquiries can be expected by DOE from various interests, ranging from the regional economic impacts of nuclear power plant development to OCS leasing, western coal development and strategic petroleum allocation plans, a variety of models should be assessed to determine their capabilities for addressing these issues and to establish the means by which direct impacts associated with energy development projects can be incorporated into their frameworks. This approach would be expected to produce more realistic regional economic and environmental analyses at various levels of disaggregation.

The Energy Information Administration (EIA) of the U.S. Department of Energy (DOE) has sought to improve its capabilities for assessing regional impacts of energy policies considered by the Agency. To meet this objective has required the investigation of possible approaches to direct regional energy/economic modeling by review of both energy data sources and regional modeling capabilities. One promising analytical framework for modeling regional energy/economic

interactions which has particularly interested EIA is a "bottom-up" state econometric modeling system developed at the Bureau of Economic Analysis (BEA), U.S. Department of Commerce.¹ However, the capabilities of this modeling system for analyzing regional energy questions had not been evaluated before this review had taken place.

This report presents the results of the evaluation of possible linkages between energy policy and regional economic models. It specifies alternative designs for modeling regional energy/economic interactions through reviews of both regional economic frameworks which model the temporal and spatial impacts of economic change and data sources and models which might be appropriate for developing energy-related inputs to these models. It then develops specific energy data linkages to the BEA econometric modeling system to determine the types of energy policies that might be most appropriately addressed by this framework. The structure of the report for presenting this information is described in the following section.

1.1. Structure of the Report

To effect the evaluation of the direct regional energy/economic design, the report is structured as follows. Chapter 2 identifies data and analytical frameworks which estimate the direct economic and demographic impacts associated with the development of localized energy facilities. Data sources include both those within the Department of Energy and elsewhere. Impacts considered include construction materials, labor requirements, and capital and resource requirements. They take into account facility lead times and the temporal patterns of labor and materials characteristic of many energy development activities.

Chapter 3 then reviews existing and developing analytical systems and assesses their capabilities for incorporating energy policy impacts into their frameworks for regional and multiregional analyses. It furthermore specifies

¹The National-Regional Impact Evaluation System (NRIES).

the kinds of energy-related questions that are most appropriately addressed through these modeling frameworks and any transformations of basic data which would be necessary to incorporate this information into recommended analytical systems. Particular attention is given to the state econometric modeling system now being developed and applied by BEA, the National-Regional Impact Evaluation System (NRIES), and to possible approaches for analyzing regional energy questions using the kind of econometric approach utilized in this framework.

Chapter 4 then applies NRIES to three scenarios developed in conjunction with DOE. Each scenario is formulated so as to demonstrate the various capabilities and weaknesses of NRIES in addressing the types of issues of interest to DOE. The three scenarios have been chosen from several. In each case the suitability of NRIES for modeling specific impacts has been assessed a priori to arrive at the scenarios actually modeled. Where appropriate, input data for NRIES are developed and discussed and methodologies for deriving input data suitable for NRIES sector definitions are outlined. The report does not discuss results of NRIES scenario simulations, however. Scenarios have been analyzed and reported by the Bureau of Economic Analysis team responsible for NRIES' applications under separate contract to DOE.

Chapter 5 summarizes our findings concerning the usefulness of NRIES for assessing regional economic and demographic impacts of energy-related issues of interest to DOE. It examines the model's input requirements, its potential for further development and its flexibility for characterizing alternative energy development strategies at both regional and national levels. Recommendations to DOE conclude the chapter.

Chapter 2

Impacts of Energy Policy Decisions

2.0 Introduction

The proposed direct regional energy/economic modeling (DREEM) framework is intended to determine the impacts of various types of energy policies. Essentially, the framework must accept quantified direct impacts expected from a given set of policies and estimate the economic, demographic, fiscal and other impacts which are generated by this initial stimulus. Direct impacts must be defined exogenously from the modeling system; indirect and induced impacts are those that are determined endogenously.

Direct impacts may therefore be defined as an exogenous stimulus to the energy/economic system under consideration. Although possibly having spatial and/or temporal dimensions, direct impacts are largely independent of the economic and demographic characteristics of the study area in which they occur. In Section 2.1, the types of policies that must be considered in the design of a DREEM framework are identified.

2.1 Energy Policies for Regional Analysis

The interrelationships between the energy system and national and regional economies are complex. Yet DOE and other federal agencies have broad authority to recommend or promulgate policies which can affect these interrelationships significantly. These policies can be classified into three basic decision categories for the purposes of determining the capabilities of candidate DREEM frameworks and assessing their relevance to DOE needs. Energy policies can involve:

- o facility development decisions, which provide for the construction of energy production, processing, consumption or transportation facilities;
- o pricing decisions, which directly impact prices of energy commodities; or,
- o allocation decisions, which affect the total energy supply or demand, and/or the spatial/temporal distribution of energy supply or demand.

This classification scheme is based upon the characteristics of the direct impacts which each of these decision categories exhibits. These categories and their associated direct impacts are discussed below. Note, however, that some policies could possibly involve combinations of decision categories.

2.1.1 Facility Development Decisions

Facility development decisions relate to policies which promote the construction and operation of specific energy production, processing, consumption or transportation facilities. An example of such decisions is DOE's involvement (both alone and with private industry) in the development of synthetic fuel production capacity. Similarly, the granting of permits for the construction or operation of energy facilities, for example, operating permits for nuclear power plants or land leasing for coal development, essentially constitute facility development decisions on the part of federal agencies. The underlying factor in a facility development decision is the direct encouragement to construct and/or operate energy facilities.

Three major direct impacts may be associated with facility development decisions. The first impact is the increased demand for labor in the host region for constructing the facility. A second set of impacts relates to greater demands for goods and services during both construction and operation stages. A third set of direct impacts is the additional energy-related outputs or services provided by the facility upon the commencement of its operation.

Each of these direct impacts has its own characteristic set of temporal and/or spatial dimensions. Figure 2-1, for example, depicts projected labor demand schedules over the construction phases of eight nuclear power plants. The materials input flows from various regions which are required to build and operate facilities, on the other hand, highlight the spatial dimensions of direct impacts. Although the temporal distributions of man-hours and the spatial distribution of materials inputs (or outputs) may vary considerably from site to site, these direct impacts are

Figure 2-1

CONSTRUCTION PERSONNEL AND SCHEDULE

William C. Metz, "Predicting the Population Influx that Accompanies a Nuclear Power Plant". Nuclear News, March, 1978. p. 49.

largely independent of the economic and demographic characteristics of the region hosting the facility. Regional characteristics become important only when considering indirect and induced impacts.

2.1.2 Pricing Decisions

Pricing decisions are those which affect the price or cost of energy supplies. Examples of pricing decisions related to energy include the crude oil entitlements program and domestic crude oil price controls. Only one major direct impact is associated with decisions of this type: the increased or decreased prices or costs for energy commodities experienced by producers and consumers, respectively.

Pricing decisions are not necessarily spatial although induced impacts associated with these decisions invariably are. For example, an exogenous change in the price of imported crude oil, given entitlements programs, is something which is experienced throughout the country; all users are required to pay more for this type of energy. Regional impacts which result, however, are likely to be differentiated by consumption characteristics, fuel switching potential, existing capital stock and other characteristics which are unique to each region. Other pricing decisions can be more regional in scope. Current natural gas pricing regulations with respect to intrastate and interstate gas prices are, in effect, regionally oriented.

2.1.3 Allocation Decisions

Allocation decisions may affect either demand (e.g., gasoline rationing or mandatory thermostat settings) or supply (e.g., the current regional gasoline allocation system). Although targeted to different sectors, demand and supply allocation decisions have as their objective the distribution of energy without regard to the price system (although they may be accompanied by induced impacts on prices). Supply interruptions can also be categorized as allocation decisions even though they are enforced by circumstances outside the control of the federal government (e.g., natural disasters or politically motivated events such as an oil embargo).

By definition, the direct impacts of supply allocation decisions almost always have distinct spatial dimensions. (An exception is an allocation decision which affects aggregate supply.) Demand allocation decisions are less spatially-oriented unless decisions are promulgated and enforced on a regional basis. Like pricing decisions, however, allocation decisions are typically far more spatially extensive than facility development decisions. Their associated indirect and induced impacts can therefore generally be expected to be greater in magnitude and spatial extent than those related to facility construction and operation.

2.1.4 Summary

This section has defined three categories of policy decisions which are relevant to the design of a direct regional energy/economic modeling system: facility development, pricing, and allocation decisions. The direct impacts which characterize each of these decisions have been described and major differences between impacts highlighted. Facility development impacts have been suggested to be localized while pricing and allocation decisions are generally spatially extensive. In either case, however, the nature and magnitude of direct impacts are generally independent of the social and economic backgrounds upon which they are being imposed.

Because each of these decision categories differentially impact national and regional economies, their analysis requires either a comprehensive modeling framework which can be manipulated at national and regional levels or several specialized models which may estimate impacts associated with one type of policy decision but not those associated with others. Clearly, the degree to which any modeling framework can accomodate these categories of policy decisions must be an important criterion in its evaluation. However, before policy decisions can be modeled and their impacts assessed, data which characterize direct impacts associated with these policies must be located or constructed. The following section discusses potential sources of information for quantifying energy policies for the DREEM framework.

2.2 Data Sources for Direct Impacts

2.2.1 Facility Development Decisions

Several good data sources exist which detail the direct impacts of large-scale energy facilities and other energy projects.

First, information contained in Environmental Impact Statements (EIS) and Environmental Assessments (EA) required by federal agencies for many energy projects represents a significant source of data. For these statements, estimates (often annual) of direct employment and other direct impacts must be developed. Since copies of these statements must be filed at the appropriate federal agencies (usually EPA), one could refer to these documents for information useful for quantifying the impacts of similar projects and/or energy projects in similar areas.

Even more useful is the Construction Manpower Demand System being developed jointly by the U.S. Department of Labor and the Tennessee Valley Authority. The Construction Manpower Demand System forecasts:

- o construction duration,
- o manpower requirements by 29 labor skill categories, and
- o capital requirements

for energy and non-energy construction projects.

Its data base also contains a record for each planned energy facility by county of location. The energy facilities considered include:

- o power plants
- o transmission lines
- o power substations
- o fuel extraction (including a categorization of extraction by detailed engineering classifications)
- o transportation

- o processing
- o deepwater ports
- o other off-shore facilities.

The supporting agencies for this project (besides DOL and TVA) include the Department of Energy (the Energy Information Administration), the Nuclear Regulatory Commission, and the Army Corps of Engineers.

Other possible sources of data on direct impacts of energy facilities include the relevant industry trade groups, such as:

- o the American Petroleum Industries;
- o the Electric Power Research Institute; and
- o the National Petroleum Council.

Finally, several sources are available which present information, by detailed economic sector, on the direct purchases of services (including construction services), equipment and materials by various energy facilities and/or sectors. These sources sometimes even differentiate direct purchases between the construction and operations period. Two of the best sources of direct purchases by specific energy facilities are:

- o the Bechtel Corporation (various publications);
- o the Battelle Pacific Northwest Labs (see, in particular, Capital Requirements and Capital Formation for Various Assumed U.S. Energy Supply Patterns).

The best single source of direct purchases by energy sectors is the detailed input/output table statistics published by the Bureau of Economic Analysis of the U.S. Department of Commerce. The transactions tables for this table are compiled from information collected for the U.S. Department of the Census business censuses, taken every five years.

2.2.2 Pricing Decisions

Policy decisions involving energy pricing usually have self-evident impacts, particularly in cases where controls are

being imposed or modified at the time of the policy statement or shortly thereafter. In cases of longer term regulation, exogenous forecasts of price increases must usually be identified to determine direct impacts of pricing decisions. For example, oil or gas decontrol which is phased-in over a multiyear period, requires that assumptions be made about price ceilings and other factors. Thus, forecasts of world prices over the period of analysis must be identified or formulated. Energy price controls which tie prices in some way to inflation (e.g., price increases equal to the gross inflation rate plus 2.5 percent) require forecasts for appropriate future inflation rates so that energy prices can be estimated. Regardless, no specific data can be identified which generally apply to direct impacts of energy pricing decisions. Rather, they must be formulated within the context in which policies have been proposed. Sufficient information should exist in policy statements, in conjunction with exogenous forecasts where necessary, to quantify the direct impacts of energy pricing decisions.

2.2.3 Allocation Decisions

As with pricing decisions, direct impacts associated with allocation decisions can only be determined from the precise language of the policy statement or regulation which effects the allocation. Gross supply or demand impacts of the allocation decision may be supplemented in policy statements by supporting data which may be used to define other direct impacts that may result. For example, a regulation which imposes minimum or maximum thermostat settings for certain classes of buildings will require supporting documentation on the number, type, location and energy use characteristics of affected buildings. Direct impacts, in this case energy savings by region and building type, can be calculated from this supportive material.

2.3 Conclusions

In this chapter we have identified three types of energy policy decisions which may be analyzed using a DREEM framework

- o facility development decisions
- o pricing decisions
- o allocation decisions.

The direct impacts to national and regional economies of each type of decision has also been defined in generic terms. It is these direct impacts which must be quantified before any analysis of induced impacts can be undertaken via a regionally-oriented economic model.

Finally, the data sources which can be utilized to identify and quantify direct impacts have been discussed in Section 2.2. By their nature, the direct impacts of facility development decisions are more easily discussed in the abstract. Thus, the discussion of data sources is far more concrete for this policy decision category than for pricing or allocation impacts. For the latter two, the content and purpose of the policy under consideration is far more relevant in determining the data sources and data requirements that must be used to estimate direct impacts.

The identification and quantification of direct impacts associated with energy policy decisions are but the initial stages of impact analyses, however. Of primary concern are the regional impacts which result from the initial stimulus upon the national or regional economies. What is required is a modeling framework with a strong regional component which is sensitive enough to assess the spatial and temporal dimensions of energy policy impacts yet capable of addressing a range of policy issues as outlined above. Thus, the assessment of alternative modeling frameworks is the purpose of Chapter 3. It reviews the analytical structures of various multiregional and regional models in order to evaluate their relevance for estimating regional impacts of energy policy decisions.

Regional and Multiregional Economic Models

3.0 Introduction

Regional impacts of economic change, particularly those related to facility development decisions, have generally been assessed using location specific impact models. These models, which estimate the indirect and induced impacts resulting from the initial direct stimulation of the region's economic base, are typically constructed and calibrated to small single or multi-county regions. Examples of energy development impact models include BOOM1 (developed at the Los Alamos Scientific Laboratory) and REAP (developed at North Dakota State University).

However, these models ignore the relationships that local areas share with other regions in the country. Facility construction, which induces population in-migration, for example, affects not only the host community but also those areas which experience outmigration to employment opportunities in or around the host community. Although in many cases these interregional impacts are likely to be negligible, particularly when substantial physical and "economic" distances separate regions, the impacts of energy policies can sometimes be severely underestimated when systemic effects are not taken into account. Furthermore, issues of equity and distribution are often major considerations in federal policy-making. Also, energy policies which are not spatially intensive, such as those related to allocation and pricing of energy resources, cannot be addressed using localized impact models.

An alternative approach to impact analysis involves the application of multiregional models of the U.S. economy. These models are regional in the sense that they characterize the economic, demographic and fiscal interactions within sub-national boundaries. But in addition, multiregional models attempt to maintain an overall national context by explicitly or implicitly recognizing the economic linkages between regions. This affords the opportunity for investigating both region-specific impacts associated with energy policies and the associated interregional impacts which may be induced. Multiregional models also provide a necessary (but not necessarily sufficient) context for assessing national pricing and allocation schemes instituted to moderate energy production or consumption.

Models of regional economic activity have conventionally been classified as being either "top-down" or "bottom-up" economic frameworks. Whereas the former typically shares-out national economic activity to regions, the latter bases its structural equations and empirical relationships upon the region under analysis, whether it be county, state or other areal definition. National economic activity, under this latter approach, is determined only upon aggregation of all regions which make up the nation (if such aggregation is possible). An intermediate approach to modeling regional economic activity is sometimes advocated, whereby bottom-up regional models are tied to exogenously determined national economic totals, either directly or iteratively. Such an approach, which characterizes the Chase regional modeling framework (Chase Econometrics Associates, Inc., n.d.), is neither strictly bottom-up nor top-down. For convenience, however, and because this class of models recognizes the structure of regional economies, we consider this approach to be bottom-up in the following review of regional economic models.

This chapter evaluates several regional economic frameworks in the context of energy policy issues discussed in Chapter 2. It assesses how the direct impacts of energy policies may be incorporated into their frameworks and how multiplier effects are calculated. The chapter first discusses top-down approaches to multiregional analysis using, as an example, the Regional Earnings Impact System (REIS) which has been applied by DOE to support the regional impact analysis in its annual report to Congress (U.S. Department of Energy, 1978). Next, problems in applying this modeling framework to issues related to facility development decisions and to pricing and allocation policies are described. Finally, alternative bottom-up conceptual frameworks are examined. Three variants of bottom-up economic models are discussed in detail: single region econometric, multiregional econometric and multiregion input-output models. Particular modeling frameworks within each of these variants are examined and assessed in the context of energy policies identified in the previous chapter. The chapter concludes by discussing the issues which can be appropriately addressed by each modeling framework.

3.1 "Top-Down" Regional Economic Models

Top-down regional economic models are formulated to quantify, explain and project regional economic activity from national economic projections. The linkage to national economic models inherent in this approach is utilized because of both the complexity involved in determining the structure of regional economies and the frequent lack of reliable regional data. From this approach have been developed several working models including MULTIREGION (Olsen et al., 1977), which estimates population and employment in BEA economic areas, OBERS (U.S. Water Resources Council, 1974) which uses shift-share analysis to estimate economic activity in 37 industrial sectors for various geographical definitions, and REIS (Sandoval et al., 1978), a modeling system which projects growth in state earnings given different assumptions about the nation's economic and energy futures. Because it is applied to analyze energy policies by the Regional Socioeconomic and Environmental Analysis Division (RSEAD) of EIA, this section briefly reviews the REIS modeling framework as a representative example of top-down regional economic modeling approaches.¹

As described above, REIS is an analytical framework which forecasts state earnings given national economic and energy assumptions. Regional industrial detail is derived through the linking of an energy sector model, a macroeconomic model, an input-output model and a regional distribution model (Figure 3-1).

The regional distribution model utilizes economic base theory, which postulates the existence of two major types of economic activities in a region, basic and non-basic (or residentiary), the latter being totally dependent upon the former. The first stage of the regional model therefore determines the level of basic activity in each state by applying BEA projections of state shares to forecast national output in those industries considered basic to the state's economy. Symbolically, basic sector earnings by state are calculated as follows:

¹This review draws heavily upon the work of Sandoval et al., (1978).

Figure 3-1

Flow Chart of the Regional Earnings Impact System

$$\sum_{j=1}^{37} \theta_{ijt} a_{ijt} X_{jt} = \bar{b}_{it} \quad (3.1.1)$$

where: a_{ijt} = BEA State-to-Nation sector ratios,
 θ_{ijt} = 1 (one) if j equals a basic sector and 0 (zero) if j equals a residentiary sector in region i ,
 X_{jt} = national sector earnings,
 $\bar{b}_{it}$ = total basic-sector earnings in region i ,
 i = 50 States plus the District of Columbia,
 j = 37 2-digit SIC economic sectors, and
 t = the year 1971, 1975-1980, 1985, 1990, 1995, or 2000. Henceforth, t will be excluded.

Region-specific shares of residentiary industry activity are then determined by applying state location quotients to national residentiary shares. These shares are then aggregated to obtain the expected total share of total earnings in each state provided by its residentiary industries, i.e.,

$$C_i = \sum_{j=1}^{37} \lambda_{ij} Q_{ij} \left[\frac{X_j}{\sum_{j=1}^{37} X_j} \right] \quad (3.1.2)$$

where: C_i = the expected share of total earnings in region i provided by all residentiary industries
 Q_{ij} = location quotient associated with industry j in region i ¹
 $\lambda_{ij} = \begin{cases} 1 & \text{if } j \text{ is a residentiary industry} \\ 0 & \text{if } j \text{ is a basic industry} \end{cases} \quad \text{in region } i$

Total state earnings are then derived from (3.1.1) and (3.1.2).

$$b_i = \frac{\bar{b}_i}{1 - C_i} \quad (3.1.3)$$

where: b_i = expected total earnings in region i given shared national earnings of basic sectors in the region.

¹Projected by BEA.

Simple factors can then be applied to these totals which, when normalized, yield expected earnings in region i from residentiary sector j. Finally, total earnings by state are recalculated by summing the earnings of basic and normalized residentiary sectors.

Although data requirements for this and other top-down models are typically modest, their simplified structure usually precludes their application to all but a limited number of policy issues. For example, REIS can accomodate scenario variations through its national energy or macroeconomic components only, since the distribution model is insensitive to parameter changes--i.e., regional shares remain invariant across scenarios. Therefore, only policies related to macroeconomic change, such as those concerning energy prices at the national level (e.g., the price of imported crude oil) or aggregate energy supplies, can usefully be characterized by this top-down framework. REIS has been applied in this context to analyze regional impacts of alternative macroeconomic and energy supply and demand paths for the Administrator's Annual Report to Congress (U.S. Department of Energy, 1978).

On the other hand, REIS lacks sufficient sensitivity to consider the more microeconomic aspects of energy development (Sandoval et al., 1978, p. 32-33), such as the economic and demographic impacts of localized facility development decisions. Regional shares from national totals, to reflect the dynamics of energy development, can only be adjusted on an ad hoc basis if the structures and interrelationships of the regional economies are not known. Even if location quotients were derived from more disaggregate data such as RIMS (Bureau of Economic Analysis, n.d.), the sharing methodology would still be unable to respond realistically to changing economic and energy conditions and constraints. The analysis of energy policy issues, especially those requiring considerable spatial detail, cannot be accomplished through top-down modeling frameworks such as REIS. Inquiries of this nature are more appropriately addressed by bottom-up modeling frameworks.

3.2 "Bottom-Up" Regional Economic Models

The bottom-up approach to regional economic modeling is the major alternative to top-down frameworks. It is one which involves the development of economic relationships and employment of data specific to the region or regions under investigation. National economic indicators can be derived by aggregating regional totals, if necessary. Under the bottom-up methodology, the regional economies, rather than the national one, are the major "drivers" of their future growth.

This report has chosen to review three bottom-up modeling approaches with which to represent regional economic development: single region econometric models, multiregion econometric models and multiregional input-output models. Although several other frameworks could be suggested for review (see, for example, Glickman, 1977, p.13-56; Ballard, 1975, p.18-47; Richardson, 1972), the three above approaches best address the needs of DOE, particularly in light of the energy policy issues described in Chapter 2.

3.2.1 Single Region Econometric Models

Econometric models constructed from a system of linear or non-linear equations are the most flexible form of model currently available for regional analysis. By the nature of their data and reasons for development, these models capture the structural relationships between economic factors which characterize the region under analysis.

By far the most advanced single region econometric models are the simultaneous equation systems, such as those developed for Puerto Rico (Dutta and Su, 1969), Alaska (Tuck, 1967), Massachusetts (Bell, 1967), Ohio (L'Esperance et al., 1968), Hawaii (Norman and Russell, 1969), Northeast Corridor (Crow, 1969), Coastal Plains States (Richter, 1970), Philadelphia (Glickman, 1969, 1971, 1974a), California (Ratajczak, 1972; Roberts and Wittels, 1971), Oklahoma (Liew and Kahng, 1971), Southern California (Moody and Puffer, 1969), Santa Clara, California (Goldman, 1965), Illinois (Green, 1967), Buffalo (Crow et al., 1974), Southeastern Ohio (Anderson, 1970), Los Angeles (Hall and Licari, 1974), and Tennessee (Gustely, 1978).

Under this scheme, regional economic activity in time t is defined by a vector, $\underline{y}_t = \{y_{1t}, y_{2t}, \dots, y_{Gt}\}$; the simultaneous structure evolves through the relating of each endogenous regional variable, y_{it} , to other endogenous variables, $\underline{y}_t$, a set of endogenous variables, $\underline{z}_t$, and a stochastic error term, $\underline{u}_t$ (Glickman, 1977, p.60)¹,

$$\underline{B} \underline{y}_t + \underline{C} \underline{z}_t = \underline{u}_t \quad (3.2.1)$$

which, in its reduced form is specified as (Kmenta, 1971, p.535):

$$\underline{y}_t = \underline{\Pi} \underline{z}_t + \underline{v}_t \quad (3.2.2)$$

where $\underline{\Pi} = -\underline{B}^{-1} \underline{C}$ and $\underline{v}_t = \underline{B}^{-1} \underline{u}_t$ and $\underline{B}$ is non-singular.

Exogenous variables are typically of two classes: lagged endogenous, $\underline{y}_{t-j}$, and extra-regional (usually national) exogenous variables, $\underline{z}_t$. Regional economic relationships can therefore be written in the following form:

$$\underline{y}_t = \underline{\Pi}_1 \underline{y}_{t-j} + \underline{\Pi}_2 \underline{z}_t + \underline{v}_t \quad (3.2.3)$$

For forecasting purposes, once $\underline{\Pi}_1$ and $\underline{\Pi}_2$ are estimated over time series data, the error term, $\underline{v}_t$, is set to zero and estimates for $\underline{y}_{t+k}$ are made by substituting forecast values of the exogenous variables, $\underline{z}_{t+k}$, into the modeling framework. This requires that we assume that the structural relationships in the regional economy, represented by the coefficient matrices $\underline{\Pi}_1$ and $\underline{\Pi}_2$, remain constant over the forecast period.

Policy and impact analyses are undertaken by examining the differences between a baseline extrapolation and forecasts which incorporate changes to selected policy variables. Direct impacts in the policy simulation are characterized by changes to the set of exogenous variables, $\underline{z}_t$, which are transmitted sectorally through the economy via the coefficient matrix, $\underline{\Pi}_2$, and temporally through the economy through changes induced in the lagged endogenous variable, $\underline{y}_{t-j}$.

¹ $\underline{B}$ and $\underline{C}$ are coefficient matrices for the endogenous and exogenous variables respectively. Each error term in the vector $\underline{u}_t$ is assumed normally distributed with mean zero.

Systems of linear equations pose an advantage over their non-linear counterparts in that the calculation of impacts does not require simulations of future activity to be run. Since this class of model can always be expressed in its reduced form, the transmission of impacts through the economy from a one-time exogenous shock to regional system can be calculated as follows. In periods $(t+j)$, $j = (0,1,2,\dots)$, the impacts from Δz_t are simply:

$$\Delta y_t = \Pi_2 \Delta z_t$$

$$\Delta y_{t+1} = \Pi_1 \Delta y_t = \Pi_1 \Pi_2 \Delta z_t$$

$$\Delta y_{t+2} = \Pi_1 \Delta y_{t+1} = \Pi_1^2 \Pi_2 \Delta z_t$$

⋮

The total impact of the one-time shock is the summation of these terms, or:

$$\Delta y = \sum_{j=0}^{\infty} \Pi_1^j \Pi_2 \Delta z_t \quad (3.2.4)$$

Similarly, a sustained exogenous shock¹ can be expected to produce a total impact (Glickman, 1977, p.71):

$$\sum_{j=0}^{\infty} \Pi_1^j \Pi_2 = (\underline{I} - \Pi_1)^{-1} \Pi_2 \quad (3.2.5)$$

Non-linear systems of equations, however, usually require both baseline and "perturbed" (Glickman, 1977, p.71) simulations to be run throughout the time-period of interest and impacts to be calculated from the differences between scenarios, Δy_{t+j} or, $n-1$

$$\sum_{j=0} \Delta y_{t+j}$$

Such is the approach taken by Glickman (1977) where the impacts of (i) an oil shortage, (ii) a public service employment program, and (iii) a revenue sharing program on the Philadelphia SMSA were assessed in an extensive regional study. Each of these policy alternatives were defined by a series of changes to selected regional and national exogeneous variables which were then substituted into appropriate equations to gauge their effects. National exogenous variables were extracted from the Wharton

¹Of equal magnitude in each time period.

Annual and Industry Model; regional exogenous variables were determined from the Philadelphia input-output table (Isard et al., 1967), which addresses a more disaggregate set of interindustry transactions, and from a survey instrument.

Not all policy analysis is as straightforward or precise, however. Often policy changes anticipated in some future time period have no comparable antecedents in the historical data upon which the model is based. These observational deficiencies preclude the correct specification of exogenous causal variables and lead to problems of identification. Typically, endogenous variables which represent not the stimulus, but rather the impacts themselves, are adjusted to reflect these policy changes. Because of the simultaneous nature of the relationships between endogenous variables, such simulations effect inconsistencies among the variables through the implicit restructuring of the calibrated relationships.

For example, in a simulation of the impacts of the Carter energy program on the state of Tennessee, to reflect nationally-assumed tax incentives for investment in insulation and solar energy, Gustely (1978) reduced residential electricity and gas consumption by ten percent below their baseline forecast levels throughout the period of analysis. However, these consumption variables are endogenous to the regional economic system, being related to the relative prices of electricity and natural gas, and total personal income in the state.

Important relationships which display the simultaneity among variables include those shown in Figure 3-2. The introduction of arbitrary values for "ln TECRES" and "ln TTGSRES" in the policy simulation run has effectively overridden the simultaneity in the modeling system. These variables are treated as causal factors in the calculation of energy prices, "ln TEPRES" and "ln TTGPRES," which, upon determination, have not been fed back into the equations for residential electricity and natural gas consumption since the specified values for these two variables would not then be achieved. Consistency, in this case, has been sacrificed in order for certain policy issues to be addressed. Whether the error introduced through this method of simulation is

Figure 3-2

Relationships Between Residential Electricity and
Natural Gas Consumption and Their Prices

$$\ln \text{TECRES} = 2.9742 - 0.4026 \ln (\text{TEPRES}/\text{TTGPRES}) + 1.5890 \ln \left(\frac{\text{TPY001}}{\text{UDPC}} \right)$$

$$\ln \text{TTGSRES} = 0.1115 \ln (\text{TTGPRES}/\text{TEPRES}) + 0.5791 \ln \text{USNGASPRD}$$

$$\ln \text{TEPRES} = 0.7172 [\ln \text{TCPR} - 0.5771 \ln \text{TCPR}_{-1}] - 0.1192 [\ln \text{TECRES} - 0.5771 \ln \text{TECRES}_{-1}] + 0.5771 \ln \text{TEPRES}_{-1}$$

$$\ln \text{TTGPRES} = -2.5755 \times (1.0 - 0.6666) - 0.1515 [\ln \text{TTGSRES} - 0.6666 \ln \text{TTGSRES}_{-1}] + 0.3943 [\ln \text{USAVGNGWHP} - 0.6666 \ln \text{USAVGNGWHP}_{-1}] + 0.6666 \ln \text{TTGPRES}_{-1}$$

TECRES = Tennessee Consumption of Electricity-Residential
TEPRES = Tennessee Electricity Price-Residential
TTGPRES = Tennessee Total Gas Price-Residential
TTGSRES = Tennessee Total Gas Consumption-Residential
TPY001 = Tennessee Total Personal Income
UDPC = U.S. Personal Consumption Deflator
USNGASPRD = U.S. Natural Gas Production
TCPR = Tennessee Coal Price at Power Plants, F.O.B. Plant
USAVGNGWHP = U.S. Average Well-Head Price of Natural Gas

Source: Gustely, 1978

significant, however, has not been determined.

But problems in adjusting forecasts to simulate policy changes apply more generally to all types of econometric models discussed in this report. More basic problems with single region models concern their inability to address more nationally-oriented pricing and allocation policy decisions, and their failure to recognize the true spatial extent of even localized energy impacts. With regard to the former, single region models, by their definition, cannot assess impacts which occur outside the boundaries of the region under consideration. Since DOE is concerned with all regions in the country, this modeling framework is particularly inappropriate for evaluating multiregional policies such as those resulting from pricing and allocation decisions. And while the sectoral and spatial detail of single region econometric models provides an excellent information base for estimating the indirect and induced impacts associated with site-specific facility development decisions, the transmission of impacts to surrounding regions is necessarily overlooked in this framework. Ballard and Wendling (1978, p.1) maintain that economic impacts of development policies outside the region can often be as large or larger than those within the host region. If this is the case, then, the economic and demographic impacts of site-specific energy development activities may be severely understated by single region models.

The type of policy under consideration or the degree to which impacts of facility development decisions are internalized within a region will essentially dictate whether single or multiregional models are employed in the analysis. When modeling localized energy development activities, for regions which are economically and demographically self-sufficient, it may be preferable to utilize regional models having considerable spatial and sectoral detail to measure impacts. On the other hand, those regions with significant leakages would be better modeled with less sectoral and spatial, but greater multiregional, detail. Policies such as those related to pricing and allocation, which have spatial dimensions broader than those considered in single region models cannot be adequately

addressed in single region frameworks. Clearly, some trade-offs between modeling frameworks are apparent which can often be resolved a priori, if a choice among modeling frameworks actually exists. However, multiregional models appear capable of addressing a wider range of policy issues than single region models and, thus, by their flexibility may provide a unified framework for implementing a DREEM design. This alternative approach is discussed in the following two sections.

3.2.2 Multiregional Econometric Models

Bottom-up multiregional models are frameworks which integrate regional models into an interactive national or subnational system. As discussed above, by accounting for the transmission of impacts among regions, multiregional models capture the total impacts of facility development policies which are geographically concentrated in a single area yet can accommodate supraregional policies as well. Furthermore, the closing of the economic environment by accounting for all regions renders individual region forecasts consistent with national economic activity, a property not usually displayed by single region models (Ballard and Wendling, 1978, p.4).

Bottom-up multiregion models which have been identified in the literature include the Curtis Harris model, the Chase Regional model, and the National-Regional Impact Evaluation System (NRIES). Another multiregional modeling approach, the multiregional input-output framework, is discussed in the next section of this report.

This section briefly reviews each of the econometric approaches identified above and assesses their capabilities for estimating energy policy impacts of the types discussed in the previous chapter.

The Curtis Harris Model

The Harris Multi-Regional, Multi-Industry (MRMI) Forecasting Model is a framework designed to predict the short-run impacts and project the long-run effects of exogenous changes in public expenditures. It is a modeling framework based upon a "location-agglomeration" approach (Lakshmanan, et al., 1977), whereby the change in output of each industrial sector is explained by two sets of variables:

(1) input prices that firms face in each location, and (2) agglomeration variables which reflect the positive externalities generated by proximate industries. The geographic unit chosen as the focal point for analysis is the county, although another version of the model considers the 173 BEA Economic Areas (Harris, 1974).

Equations in the model forecast industrial and construction output, employment, population, personal income, personal consumption, government and defense expenditures, gross investment for a number of industries and marginal transport costs. All equations are estimated by Ordinary Least Squares (OLS) regression methods; marginal transport costs are obtained from a linear programming solution to a transportation cost minimization problem.

The model is recursive in that supply and demand data in year t are used to forecast variables in the year $t+1$. The forecasts are then used as data to make forecasts for the year $t+2$, and so on.

The forecasting model starts by estimating output by industry in each region for the first year after the base year (1965). The output or change in output of each industry sector is explained by the marginal costs or prices that firms face in each region. After output has been determined, then payrolls, employment, population and personal income are derived. The final demand sectors are also forecast. Consumption and governmental expenditures are related to income; investment is related to output; and, foreign exports are determined exogenously.

The parameters for each equation in the model have been estimated from a cross-sectional data base composed of 3,111 observations, where each observation represents a county in the U.S. The base year for the model is 1965, the only year for which a complete set of data for all counties was available. The Harris model also uses dummy variables for each of the regional observations to capture some of the variation in dependent

variables not fully explained by explanatory variables. Harris assumes there is some unique constant in every county that is not being explained by a particular equation. Therefore, there is a separate, though parallel regression line for each county.

The following assumptions characterize the Harris model:

- (1) "Average" national production functions embodied in estimated regression coefficients can be uniformly applied at the regional level,
- (2) Changing shares in regional production resulting from changes in transportation costs underlie the shifting location of regional industries,
- (3) There are no abrupt changes in any regional economy, but rather the changes that do take place result from the gradual adoption of innovative technology.

Although it may be argued that the assumptions which, in effect, postulate uniform economic structure among regions, invalidate the model's application to regional impact analysis, the specification of relationships in terms of change in activity, rather than absolute values, enables each of the regional units under analysis to be differentiated. Underlying structural relationships are assumed to be the same across counties; firms respond identically to changing economic conditions whether located in Massachusetts or Arizona, but each region does not necessarily have the same proportions of activity at any given time (Krutilla et al., 1978, p.30).

The major "driver" of the model is the set of output equations for non-construction industrial activity, which relates by a system of first-order difference equations the change in output in a given industry i and region j to a set of variables from the previous time period $(t-1)$.¹

Thus:

¹A complete specification of the model is given in Harris (1973, p.9-31).

$$\Delta Q_{ij}^t = f_i \left(TQ_{ij}^{t-1}, TI_{qj}^{t-1}, WR_{ij}^{t-1}, VL_j^{t-1}, Q_{ij}^{t-1}, EQ_{hj}^{t-1}, \right. \\ \left. DEN_j^{t-1}, MB_{ijk}^{t-1}, MS_{ijk}^{t-1} \right) \quad (3.2.6)$$

- where: ΔQ_{ij}^t = the change in output in sector i region j from time period (t-1) to t.
- TQ_{ij}^{t-1} = transport cost of shipping a marginal unit of output for sector i out of region j in t-1.
- TI_{qj}^{t-1} = transport cost of obtaining a marginal unit of input from industry q into region j in t-1.
- WR_{ij}^{t-1} = annual earnings per worker in labor sector i working in region j in t-1.
- VL_j^{t-1} = value of land per acre in j in t-1.
- Q_{ij}^{t-1} = output of industry i in region j in t-1.
- EQ_{hj}^{t-1} = equipment purchases by equipment purchasing sector h in region j in t-1.
- DEN_j^{t-1} = population density in region j in t-1.
- MB_{ijk}^{t-1} = major buying sector k located in region j that bought goods from i in t-1.
- MS_{ijk}^{t-1} = major supplying sector k in j that sold goods to i in t-1.

Gross investment, construction output and employment all are based upon these output equations directly, while population, labor force, income, personal consumption expenditures and international trade are indirectly linked through one or more of these recursive components.

The multiregional character of the model results from transportation variables introduced into the location equations, TQ_{ij}^{t-1} and TI_{qj}^{t-1} . Costs of shipping a marginal unit of product both out of and into each region reflect the comparative advantages of the regional unit with respect to surrounding areas. In this way, the competitive economic structure among regions is recognized.

Given both the temporal and block recursive structure of the Harris model, the introduction of direct impacts to the system of

equations is straightforward. Direct impacts are introduced as exogenous variables in appropriate equations in the model; indirect impacts are then calculated either in the same year, t , through modified endogenous variables which are utilized further down the recursive scheme, or in the following period, $t+1$, through substitution of lagged endogenous variables.

The model's recursive structure and degree of industry detail (99 industry sectors, 4 other labor sectors, 2 import sectors, 69 equipment purchasing sectors, 28 construction sectors, 8 government sectors, 4 age cohorts and 2 race groups) make it a potentially useful regional analytical system for determining the energy policy impacts, particularly those related to facility development decisions.

Krutilla et al. (1978) have applied the model to analyze the economic and fiscal impacts of Northern Great Plains coal development. Here, four coal development strategies were postulated for the Big Horn and Rosebud county areas of Montana involving selected combinations of coal production levels (number of mines), coal conversion facilities, and coal-fired electric utilities. Primary input data to the model representing the direct impacts associated with these development strategies were derived from both private and public sources. For example, data on dollar outlays for investment in plant and equipment, man-years of construction and operating labor and tons of output for coal mines of a given capacity (10 million tons annually) were derived from private industrial sources. Similar data for power plant construction and operation¹ and for the construction of a 250 million cubic feet/day coal gasification plant² were gathered from public sources. These data incorporated the temporal variations of capital and labor throughout the development of these facilities, and enumerated employment required for plant operation.

¹U.S. Atomic Energy Commission, Power Plant Capital Cost Trends and Sensitivity to Economic Parameters. Division of Reactor Research and Development, 1974.

²Federal Energy Administration, Report to Project Independence Blueprint. Prepared by Inter-Agency Task Force on Synthetic Fuels from Coal, U.S. DOI, 1974.

In addition to outputs of the Harris model, separate tax revenue and local public sector expenditure models were developed to address fiscal impacts of the alternative development strategies as well. Unlike the multi-regional, multi-industry forecasting model, however, these latter models were geographically and functionally specific to the region under analysis.

Impacts associated with alternative scenarios were forecast by applying the Harris model, plus additional submodels, to only the two counties under investigation. Its application was therefore more of a regional than multiregional exercise. By taking this approach, economic, demographic and fiscal impacts were acknowledged to likely be overstated (Krutilla et al., 1978, p.36), since all effects of the alternative energy development strategies were implicitly assumed to be internalized within the political boundaries of the two counties. But it is not clear whether the model's application over a wider geographical area would eliminate this problem of overstatement. Since the interregional linkages are implicit rather than explicit, the model, instead, may only be a means of determining upper bounds to impacts likely to result from economic development strategies.

The model's capabilities for assessing other policies, such as pricing and allocation decisions, are not as clear. The absence of explicit price-quantity relationships in the model essentially precludes investigations of regional energy pricing scenarios in this framework. Regional impacts of macroeconomic price changes, however, to the extent that they are addressed in Almon's INFORUM model (Almon, et al., 1974)--the macroeconomic and national input-output drivers of the Harris model--could potentially be estimated in this multiregional framework. The transportation linear programming sub-model could also possibly be used to investigate alternative energy allocation decisions, although not enough of this model's specification is known to accurately assess its capabilities in this area. No applications related to these types of policies have been found in the literature. Clearly, the Harris model's strengths lie in its spatial and sectoral detail which encourage its application in more micro- rather than macro-economic energy policies.

The Chase Econometrics Regional Forecasting Model

The Chase regional forecasting system is a multiregional modeling framework which drives off both national and regional variables (Figure 3-3). The system is essentially block recursive: manufacturing output, disaggregated to the 2-digit SIC code level, and calculated initially by the model, is a major determinant of manufacturing employment; non-manufacturing employment is estimated from an economic base-type framework using several manufacturing output variables;¹ regional employment variables then partially determine personal income which, in turn, is input to consumer purchases and financial sector blocks of the model. Agricultural output and population by age cohort and race are forecast exogenously to the multiregional framework. In addition to regional economic forecasts for the fifty states, the model forecasts economic activity for 114 metropolitan areas.

Regional manufacturing activity--the driving force of the model--is estimated as a function of three major classes of variables: national demand, comparative costs, and a region-specific short-term cyclical variable. National variables are input to these equations to address the importance of extra-regional demand upon manufacturing sector output levels. Furthermore, they ensure that regional demands, when aggregated, remain consistent with national forecasts.

Comparative cost variables relate to regional factor prices which affect the profitabilities of firms doing business in the region. The model assumes a direct relationship between relative profitability and costs, and locates industry in regions where their costs are lowest. Because of the different input requirements for different sectors, these variables are primary determinants of the secular development of regional economies. Relative costs by region include energy, labor, materials, land and other factor costs, which are exogenously forecast for future years for input to simulation runs.

The short-term cyclical variable serves to capture the nature of capital plant and equipment in the region. Older, less efficient plant

¹This block of the model is currently undergoing revision to better reflect regional variations in basic/non-basic sector relationships.

Chase Regional Economic Model

The flowchart illustrates the Chase Econometrics model, showing the relationships between various economic variables. The model is organized into several layers of boxes, with arrows indicating the direction of influence. A dashed line separates the top layer of policy and indicator variables from the bottom layer of activity and income variables.

Top Layer (Policy and Indicators):

- Monetary Policy
- Government Spending
- Wage Rates and Prices
- Cyclical Indicators
- Manufacturing Output
- Capacity Utilization

Regional Variables: A dashed line separates the top layer from the bottom layer, with the label "Regional Variables" centered below it.

Bottom Layer (Activities and Income):

- Construction
- Farm, Mining Activity
- Non-Manufacturing Employment
- Manufacturing Employment
- Total Employment
- Labor Force and Unemployment
- Personal Income
- Consumption
- Deposits
- Loans

Key Relationships and Feedback Loops:

- Monetary Policy** influences **Construction**, **Deposits**, and **Loans**.
- Government Spending** influences **Construction**, **Non-Manufacturing Employment**, and **Personal Income**.
- Wage Rates and Prices** influence **Non-Manufacturing Employment**, **Manufacturing Employment**, and **Personal Income**.
- Cyclical Indicators** influence **Non-Manufacturing Employment** and **Manufacturing Employment**.
- Manufacturing Output** and **Capacity Utilization** influence **Manufacturing Employment**.
- Construction** influences **Non-Manufacturing Employment** and **Personal Income**.
- Farm, Mining Activity** influences **Non-Manufacturing Employment** and **Personal Income**.
- Non-Manufacturing Employment** and **Manufacturing Employment** both influence **Total Employment**.
- Total Employment** influences **Labor Force and Unemployment** and **Personal Income**.
- Labor Force and Unemployment** influences **Personal Income** and **Consumption**.
- Personal Income** influences **Consumption** and **Deposits**.
- Consumption** influences **Loans** and **Monetary Policy** (via a feedback loop).
- Deposits** and **Loans** are interconnected, with **Loans** influencing **Monetary Policy** and **Construction**.

Source: Chase Econometrics, Inc. (n.d.)

Source: Chase Econometrics, Inc. (n.d.)

and equipment are assumed to be the last used and first shut down during swings in the business cycle, since they are less efficient and thus, less profitable. Regions with modern facilities are therefore expected to experience more moderate cyclical output trends than other regions. These trends are reflected in a cyclical capacity utilization variable input into manufacturing output equations.

Given its structure, the model appears particularly appropriate for assessing the regional impacts of different macroeconomic futures and of regional variations in energy prices, and has been used as a policy analysis tool for these purposes. However, there are several characteristic features of the model which indicate its limited applicability to the analysis of economic and demographic impacts associated with facility development decisions.

First, because the model does not explicitly recognize non-residential construction or equipment investment sectors in its framework, direct energy impacts associated with development cannot be input in a consistent fashion. The recursive structure requires value-added and direct employment impacts to be specified for the 2-digit SIC industries over the simulation period. Although the model captures some indirect effects from these impacts, it would appear that the absence of a non-residential construction block in the model would lead to significant estimation errors.

Second, and more important, the model cannot address the inter-regional transmission of impacts from economic development activities. Regional differentiation is based only upon comparative costs and regional cyclical variables--both are essentially exogenous to the model. Once determined, each state's economic growth is forecast independent of the others. The model lacks either the simultaneous or iterative structure required to incorporate these interregional economic and demographic interactions.

Given the model's shortcomings with respect to non-residential construction activities and its relatively aggregate industrial detail, the Chase modeling framework offers no real advantages for modeling the regional impacts of facility development decisions over the more disaggregate and detailed models such as the Harris model. (Some

forecasting capabilities could be gained from the SMSA detail of the Chase model.) And the model's failure to recognize the interregional component of impact transmission limits its applicability in multiregional impact analyses as well. The model does provide an analytical framework for investigating the regional impacts of energy pricing decisions, but here again, the absence of explicit economic interrelationships between regions can be expected to introduce considerable error into regional impact estimates. Furthermore, no mechanisms exist in the model for estimating impacts associated with energy allocation decisions. This would suggest the Chase model to hold only limited potential for incorporation into a DREEM framework.

The BEA National Regional Impact Evaluation System (NRIES)

NRIES may be described as a multi-state interactive model of the U.S. economy. It contains 51 regional models (50 states and the District of Columbia) and is intended as a medium range (5 to 10 year) forecasting methodology for estimating regional and national trends. It includes sufficient detail to estimate the regional and national impacts of a wide variety of policy alternatives.

As mentioned previously, separate state models are incorporated into NRIES. Also, a portion of the model deals with national aggregates (determined by the sum of state economic activities) and other necessary indicators of U.S. economic activity (e.g., interest rates). The state models are constructed so that economic output for each particular industrial sector in that state is expressed as a function of three types of variables: the other types of economic activity within the state, the economic or demographic interaction with other states, and certain national variables. The interaction variables are indices of economic activity in other surrounding states and are based on the gravity or "distance deflated demand" concept applied originally to the Delaware Valley multiregional model developed by Ballard (1975).

In its present form there are approximately 230 (of which 75 are behavioral) equations in each state model. There are also approximately 20 behavioral equations for the national part of

the model. Thus, the full NRIES model system has approximately 4,000 behavioral equations and 11,000 total equations. As such it is a significantly larger model than the Delaware Valley model; however, by being a state level model it enjoys a more reliable and easier to obtain data base.

Ballard (1975) has given the following technical description of NRIES using matrix notation. The notation necessary to this description is summarized in Table 3-1. The principal econometric relationship applied in each region is

$$\underline{r}_t^x = \underline{A} \underline{r}_t^x + \underline{B} \underline{r}_t^{*z} + \underline{C} \underline{r}_t^{*N} + \underline{r}_t^u. \quad (3.2.13)$$

The first term on the right-hand side, $\underline{r}_t^x$, is a vector of region-specific endogenous variables that are determinants of regional economic activity. The second term, $\underline{r}_t^{*z}$, is a vector which includes both regional and national exogenous variables, and is partitioned as shown in equation (3.2.7).

$$\underline{r}_t^{*z} = \left[\begin{array}{c} r_{z_t}^1 \\ \vdots \\ r_{z_t}^p \\ \hline z_t^{p+1} \\ \vdots \\ z_t^{p+s} \end{array} \right] \left\{ \begin{array}{l} \text{regional exogenous} \\ \text{variables} \\ \text{national exogenous} \\ \text{variables} \end{array} \right. \quad (3.2.7)$$

The third right-hand term, $\underline{r}_t^{*N}$, is a vector describing the activity that is usually exogenous to a particular state (region) but is endogenous to the complete NRIES model. Similar to the

Table 3-1

NRIES NOMENCLATURE

- n = The number of regions (51)
 i = The number of endogenous variables within each region (200)
 q = The number of exclusively national endogenous variables (70)
 p = The number of exogenous variables within each region (15)
 s = The number of exclusively national exogenous variables (25)
 r = Designation for 'home' region
 t = Designation for the time period
 $*$ = Designation exclusively for national characteristics within a regional activity vector.
 x_t^r = For each region r , is a $(i \times 1)$ vector of endogenous variables, for time period t
 x_t^{rj} = Regional endogenous variable j , in region r , for the time period t
 x_t^j = National endogenous variable j , for time period t
 z_t^{r*} = For each region r , is a $(p+s \times 1)$ vector of exogenous variables, for each time period t . The $p+1$ to $p+s$ elements are the same for each region.
 z_t^{rh} = Regional exogenous variable h , in region r , for the time period t
 z_t^h = National exogenous variable h , for time period t
 N_t^{r*} = For each region r , is a $(2i+q \times 1)$ vector of national endogenous variables or indices, for time period t . The $i+1$ to $2i+q$ elements are the same for each region.
 g_t^{rj} = The interaction indices for regional endogenous variable j , relating to region r , for time period t
 d_{rk} = Distance scalar between regions r and k (symmetrical)
 U_t^r = For each region r , is a $(i \times 1)$ vector of stochastic error terms, for time period t
 U_t^2 = Is a $(q \times 1)$ vector of national stochastic error terms, for time period t
 N_t^2 = Is a $(i+q \times 1)$ vector of national endogenous variables containing the $i+1$ to $2i+q$ elements from the N_t^{r*} vector, for time period t
 Z_t^2 = Is a $(s \times 1)$ vector of national exogenous variables containing the $p+1$ to $p+s$ elements from the z_t^{r*} vector, for the time period t
 A, B, C, D, E are matrices of coefficients

Z-vector, the N-vector is also partitioned, but into three element sets as shown in equation (3.2.8):

$$r^*_{\underline{N}_t} = \left[\begin{array}{c} r_{g \cdot x_t^1} \\ \cdot \\ \cdot \\ r_{g \cdot x_t^i} \\ \hline x_t^1 \\ \cdot \\ \cdot \\ x_t^i \\ \hline x_t^{i+1} \\ \cdot \\ \cdot \\ \cdot \\ x_t^{i+q} \end{array} \right] \left\{ \begin{array}{l} \text{interaction indices} \\ \\ \text{national aggregates} \\ \\ \text{national stochastic components} \end{array} \right. \quad (3.2.8)$$

The model specification is completed by equations which describe economic interactions among states based on distance deflated demand, national aggregates, and the truncated national model description used to estimate the national stochastic components:

$$r_{g \cdot x_t^j} = \sum_{\substack{k=1 \\ k \neq r}}^n \frac{x_t^{kj}}{d_{rk}} \quad (3.2.9)$$

$$\underline{N}_t^{i+j} = x_t^j = \sum_{r=1}^n r_{x_t^j} \quad (3.2.10)$$

$$^2 \underline{N}_t = \underline{D}^2 \underline{N}_t + \underline{E}^2 \underline{Z}_t + ^2 \underline{U}_t. \quad (3.2.11)$$

There are a number of distinguishing characteristics of the NRIES model. First, NRIES, following the original suggestion of Klein (1969), simultaneously determines the level of both national and regional activity. This contrasts with both existing top-down multiregional models and most bottom-up approaches described above. In the latter case, most modeling frameworks are still tied or constrained to national control totals. For example, the Curtis Harris model takes county-level shares determined by the model and applies them to an aggregate national model, in this case INFORUM (Almon et al., 1974), to calculate economic parameters. The Chase model uses national indicators as independent variables. The advantage of the NRIES framework in this context is that the model is capable of determining the effects that changes in regional activity have on the nation as a whole.

Second, by integrating regional and national models again along the lines originally suggested by Klein (1969), the NRIES structure ensures that the sums of regional activities are consistent with (but not necessarily constrained to) forecasts of national activity. This avoids the frequent failing of individual state models which produce overly optimistic forecasts of growth (because of their "openness") when no national framework is present.

But more important, because it is a truly interregional model, it can be used to analyze interjurisdictional transmissions of policy impacts. Interaction relationships characterizing trade between the region and all other areas are simultaneously estimated for all state models. Thus, output in one state will, by the nature of the system of equations, be affected by output in others. The nature, strength and significance of a given set of relationships will depend upon the distance separating the areas, the relative supply of the product represented in the relationships in each region and the mobility of the product (Ballard and Glickman, 1977, p.164).

That NRIES can be applied to analyze the regional and inter-regional implications of policy initiatives can be seen in a recent paper by Ballard and Wendling (1978), where the model was applied to assess the regional impacts of a national policy change by the Federal government to reduce the unemployment

rate. (The means by which policy changes are incorporated into the modeling framework are discussed in the next chapter.)

However, although the number of equations which make up NRIES is enormous, the BEA system suffers from lack of sectoral and spatial detail. Industrial activity is broken down only to the 1-digit SIC code level of detail and sub-state interactions are not modeled. There are, furthermore, no SMSA/non-SMSA type sub-models in the system. However, this detail has been removed in order to explicitly capture the inter-state economic and demographic interactions ignored in most other modeling attempts. This would suggest that at least conceptually, NRIES provides an appropriate multiregional econometric framework for estimating regional impacts.

The types of policy issues best addressed by this modeling framework are two. First, policies which alter macroeconomic parameters can be analyzed by exogenously estimating the macroeconomic impacts and inputting these new values into appropriate equations in the model. However, the range of macroeconomic policies which can be directly analyzed in this way is limited since few macroeconomic indicators are used by NRIES. A second set of issues which NRIES is capable of analyzing are those related to facility development decisions. Annual state-level impacts of energy development scenarios can be directly substituted into appropriate equations in the model and, in this manner, can be simulated over the period of interest. Note, however, that policies related to pricing and allocation decisions cannot be addressed by NRIES since prices are not considered in the model and products are transmitted interregionally via deterministic relationships which do not respond to alternative demand and supply patterns.

Summary

The multiregional econometric models reviewed in this section are all essentially bottom-up frameworks which can be used to address a subset of policy issues likely to be of interest to DOE. Specifically, the Harris model and NRIES have been found to be appropriate frameworks

for assessing impacts associated with localized facility development decisions. They may also have limited capabilities for evaluating selected macroeconomic policies. The Chase regional model, on the other hand, has been found to be sensitive to changing regional energy prices, which would make it an appropriate framework for assessing impacts associated with energy pricing decisions. However, the Chase model is somewhat limited as a multiregional framework in its failure to explicitly recognize interregional impact transmissions likely to occur between regional economies. None of the econometric frameworks appears particularly suited to the analysis of energy allocation decisions except, perhaps, indirectly through policy impacts on macroeconomic variables which, in turn, affect regional ones.

An alternative multiregional framework exists, however, which may be relevant to the development of a DREEM system. This framework, multiregional input-output, is discussed in the following section.

3.2.3 Multiregional Input-Output Models

Multiregional input-output techniques represent the earliest and most rigorously researched form of interarea analysis. Numerous state-level or other regional input-output models have been developed over the past two decades, but there have been no attempts to construct a complete, "pure" interregional table¹ covering the entire United States, primarily because of excessive computational and data requirements.

To circumvent these requirements, "balanced" (Ballard, 1975)² or "fixed column coefficient" (Polenske, 1970) models, such as the multiregional input-output (MRIO) model, which do not detail interarea trade flows, have been developed. These models identify purchases by the location of purchasers without regard to the location of producers. Trade flow matrices are used to calculate total inputs of a commodity required by an industry located in a particular region.

¹A complete, "pure" interregional I/O table would include trade coefficients which describe region and industry of origin and destination for all interarea trade.

²This should not be confused with the Isardian concept of a balanced I/O model, which recognizes a hierarchy of goods defined by the scale of the regional market (scale defined in terms of physical size--e.g., national, regional, local).

The basic structure of the MRIO system is shown in matrix notation below. The vector of outputs by sector and region is determined by the fundamental identity:

$$\underline{X} = \underline{C}(\underline{\hat{A}}\underline{X} + \underline{Y}) \quad (3.3.1)$$

where:

m is number of industries

n is number of regions

$\underline{\hat{A}}$ = matrix, $nm \times nm$, of regional technical coefficients with each of the n blocks located along the main diagonal. Each block contains the technical coefficients of the industries for a specific region. For example, the first block contains the technical coefficients for the industries located in the Northern region, the second block those for the industries located in the Southern region, and the third block those for the industries located in the Western region. The elements of the off-diagonal blocks are equal to zero.

$\underline{C}$ = matrix, $nm \times nm$, with each of the diagonals of the n blocks containing the trade coefficients. All of the off-diagonal elements are equal to zero.

$\underline{Y}$ = vector, $nm \times 1$, of final demand, with each element representing the amount of each good that is produced and sold directly to final users in each of the other regions.

$\underline{X}$ = vector, $nm \times 1$, of total output.

The elements in each regional input-output table are represented as follows:

x_{ij}^{go} = the output produced by industry i in region g and used as input by industry j in all regions. (A zero subscript or superscript is used to indicate a summation over all regions or industries.)

x_{oj}^{oh} = the input from all industries, in all regions, used by industry j in region h .

The technical input coefficients are calculated for each industry in each region by dividing each element of the appropriate column by the sum of the column (total input). Thus, the matrix is column-standardized. The technical coefficient, a_{ij}^{oh} , represents

the fraction of input from industry i in all regions used by industry j in region h.

$$a_{ij}^{oh} = x_{ij}^{oh} / x_{io}^{oh} \quad (3.3.2)$$

The trade coefficient is the fraction of an industry's output that is produced in region g and shipped to region h.¹

$$c_{io}^{gh} = x_{io}^{gh} / x_{io}^{oh} \quad (3.3.3)$$

Equation (3.3.1) shows the basic input-output relationship of the model system. Here, interregional outflows are determined by interindustry demands (CAX) and consumption demand (CY) for all regions. Alternately, the change in output can be calculated as the requirements created by a change in final demand.

$$\Delta X = \left[\underline{C}^{-1} - \underline{\hat{A}} \right]^{-1} \Delta Y \quad (3.3.4)$$

Equation (3.3.4) is the primary analytical tool for estimating impacts in the MRIO framework. Direct impacts are characterized in the model by a change in final demand (ΔY) which is transferred through the regional economies to effect changes in regional outputs (ΔX). Impacts are transmitted through regions via the trade coefficient matrix (C). Since final demand is composed of personal consumption expenditures (PCE), gross private capital formation (GPCF), state and local government expenditures, federal government expenditures, net inventory change and net foreign exports, a wide range of policies can be evaluated. For example, facility development scenarios in a region can be accommodated through changes in the PCE and GPCF columns of regional final demand. Other measures of policy impact beyond output changes, such as employment and income impacts, can be calculated using appropriate multipliers.

Note, however, that the MRIO model cannot as easily assess energy price and allocation policies. With regard to the former, the MRIO model is demand-driven and does not explicitly relate outputs to prices. Allocation policies could conceivably be analyzed by manipulating coefficients in the trade coefficient matrix, although data requirements

¹Originally, the conceptual design of the MRIO model included a trade parameter which related the cost of transferring a commodity from one region to another (see Polenske, 1970). However, inadequate data were available to implement this feature.

for developing scenarios are likely to be significant.

However, multiregional input-output models have been extended to enable them to account for impacts associated with multiregional allocation policies. The most relevant of these is the integrated interindustry and energy model developed by Goettle, Cherniavsky and Tessmer (1977) at the National Center for Analysis of Energy Systems of the Brookhaven National Laboratory. In their model, the energy sector is represented in a detailed multiregional linear programming model which is an extension of the Brookhaven Energy System Optimization Model (BESOM). It optimally allocates regionally produced energy resources and selects the optimal regional mix of energy supply, conversion, and demand technologies according to least cost or other criteria (e.g., an aggregate environmental index, or foreign energy imports) to meet projected regional energy demands. Regions are linked by both imports and exports of natural resources and converted fuels or products, including electricity. Resources are characterized by region specific supply functions, and regional demands are specified in terms of functional end uses. The energy LP model includes the following sectors (by region)

- o resource extraction activities
- o renewable resource activities
- o resource conversion to non-electric intermediate energy forms (IEF)
- o production of non-electric IEF
- o usage of non-electric IEF
- o end-use demands
- o electric utilities.

Constraints recognized in the system include

- o regional resource availability
- o regional non-electric IEF availability
- o other capacity constraints
- o distinctions between existing and new capital items
- o non-substitutability of certain IEF's for certain end-use demands
- o export/import limitations
- o environmental residuals produced
- o relationship between electricity and coproduct generation.

The interindustry model of the economy utilizes a multiregional Leontief I/O model similar in formulation to Polenske's MRIO model --that is, it is a "fixed column coefficient" I/O model, as defined by Polenske. The general model is described by the same equations as in (3.3.1) and (3.3.2), and trade flows are handled in the same manner. However, the level of spatial and industry detail is far less than the MRIO model. The Brookhaven interindustry multiregional input-output model regionalizes to only 9 U.S. Census divisions and contains only 30 industrial sectors. (This may be contrasted with Polenske's 51 regions and 79 industries in the MRIO model.) The interindustry structure of the model is outlined in Table 3-2, and an expanded notational representation of equation (3.3.1) is shown in Figure 3-4.

The most significant feature is the characterization of the energy sectors. Raw fuels (items 1, 2, 3 of Table 3-2) are distributed to sectors producing traditional energy forms (items 4, 5, 6). The output of these sectors (S) is distributed to eight dummy energy product sectors (P), which define nonsubstitutable end-use demands for energy.

Final consumption to meet end-use energy demands is respecified in terms of energy products (P) rather than in terms of generated electricity and specific fuels. In this way, substitution among energy supplies is permitted and a single production function for each of the non-energy sectors suffices. Technological change associated with fuel substitution is localized in the production functions of the energy supply/conversion sectors (S) and the energy product sectors (P).

The model is thus specified in such a manner that own-fuel substitution effects in regional trading patterns and inter-fuel substitution effects in the satisfaction of regional end-use demands can be reflected by changes within only the $\underline{C}_S^i$, $\underline{A}_{SS}^i$, and $\underline{A}_{SP}^i$ submatrices.

The rationale for linking the energy model to the interindustry model is to provide the mechanism by which trade, conversion technology, and fuel substitutions are generated. The integration task consists of aggregations of the detailed supply, conversion and demand categories

Table 3-2

Interindustry Structure for Multi-Regional
Input-Output Model

<u>Energy Supply Sectors (S)</u>	<u>Non-Energy Sectors (N)</u>
1. Coal Mining	16. Agriculture
2. Crude Oil Extraction	17. Non-fuel Mining
3. Gas Extraction	18. Construction, n.e.c.**
4. Refined Petroleum Products	19. Public Utility Construction
5. Gas Utilities	20. Durable Good Mfg., n.e.c.
6. Electric Utilities	21. Non-Durable Good Mfg., n.e.c.
7. Other*	22. Iron and Steel Mfg.
	23. Aluminum Mfg.
	24. Petrochemicals
<u>Energy Product Sectors (P)</u>	25. Transportation Services
8. Ore Reduction Feedstocks	26. Communication Services
9. Chemical Feedstocks	27. Wholesale and Retail Trade
10. Motive Power	28. Finance, Insurance, & Real Estate
11. Process Heat	29. Services, n.e.c.
12. Water Heat, Cooking	30. Business services
13. Space Heat	
14. Air Conditioning	
15. Electric Power	

*Defined as Solar and Geothermal Direct Heat Use and Electricity Generation from Pumped Storage Plants.

**n.e.c. = Not Elsewhere Classified.

A Matrix Representation of the Regional Interindustry Model*

[illegible]

$$\begin{bmatrix} \underline{\underline{C}}_S^{ik} & 0 & 0 \\ 0 & \underline{\underline{C}}_P^{ik} & 0 \\ 0 & 0 & \underline{\underline{C}}_N^{ik} \end{bmatrix}$$

$\underline{\underline{A}}^i$ = matrix of interindustry technical coefficients for region i

$\underline{\underline{A}}^i_{SS}$	$\underline{\underline{A}}^i_{SP}$	0
$\underline{\underline{A}}^i_{PS}$	0	$\underline{\underline{A}}^i_{PN}$
$\underline{\underline{A}}^i_{NS}$	0	$\underline{\underline{A}}^i_{NN}$

*Expanded from the identity $\underline{X} = \underline{C} [\underline{AX} + \underline{Y}]$

of the energy LP model to their corresponding but more generalized sectoral representatives in the interindustry I/O model.

The advantages of this approach are as follows:

- o Intraregional inter-fuel substitution and variable interregional trade patterns precluded in a standard I/O model are allowed in the LP formulation
- o Although the interindustry (I/O) formulation may accept structural overrides from the LP in regional energy production, conversion and consumption activities, it preserves the dependency of the energy sector on the economy in which it is embedded
- o Explicit incorporation of technical change and industrial migration in export base industries can be made. It is then necessary only to assume that the secondary industries have fixed technologies and that the partial multipliers on them are constant with respect to variations in regional final demands, regional industrial activity, or interregional industrial migration.

The Brookhaven LP/multiregional input-output model is a natural framework for estimating impacts associated with energy allocation decisions since the distributional elements of energy production and consumption activities are explicitly recognized. Policy scenarios are incorporated into the modeling system by modifying or adding to constraints governing the energy allocation process. It may also be conceivable to use this modeling framework to estimate regional price impacts, as well, by manipulating cost matrices or relating price changes to dual variables in the LP formulation. However, although the model can address spatially extensive energy policy issues, its regional and sectoral detail is such to make it relatively insensitive to impacts generated by facility development decisions. The model is simply too gross for estimating indirect impacts associated with localized energy development activities.

Multiregional input-output models provide an alternative conceptual framework to econometric models for estimating the indirect and induced impacts which may be associated with energy policies. They are models which explicitly and formally account for inter-industry and interregional relationships, and typically contain greater industrial detail than

multiregional econometric modeling systems. Furthermore, multiregional input-output models can be coupled to linear programming models to provide a consistent energy/economic framework for generating optimal economic responses to different energy supply scenarios. (The LP/multiregional input-output modeling system actually defines a complete DREEM design.)

However, several shortcomings of multiregional input-output models can be identified. For example, except when coupled to interregional programming or other allocation models, the multiregional input-output framework is most capable of estimating only those impacts associated with localized facility development policies since the framework lacks price sensitivity and cannot, by itself, redistribute trade flows given new economic conditions. Multiregional input-output models are therefore most appropriately applied to the same types of policy issues as multiregional econometric models. And although these models typically contain greater industrial sector detail than multiregional econometric models, their relatively unsophisticated impact indicators usually preclude the examination of all but the most basic kinds of impacts which can be expected to manifest themselves in host and surrounding regions. Regional output, employment and income impacts can be derived from forecasts by applying appropriate multipliers, but typically demographic and fiscal impacts can only be estimated exogenously to the input-output framework via additional models. In contrast, multiregional econometric models usually contain detailed sub-blocks which endogenously consider demographic and fiscal impacts associated with economic change.

Clearly, trade-offs exist between alternative modeling frameworks which must be considered in the selection of an appropriate regional economic component for DREEM. Issues relating to spatial and sectoral detail, policy sensitivity and model reliability are among those which can be expected to influence the resulting DREEM design. These issues are discussed in detail in the following section.

3.3 Synthesis

The preceeding sections have briefly discussed regional and multi-regional modeling approaches which may be useful for analyzing the regional and interregional impacts of alternative energy policies. The chapter has identified two fundamental frameworks with which to forecast regional economic activity--"top-down" and "bottom-up"--and has found that for the types of inquiries addressed by the Regional Socioeconomic and Environmental Division of DOE, top-down modeling schemes which simplistically share-out national totals are inappropriate; bottom-up regional and multiregional frameworks, because they explicitly recognize sub-national sectoral and spatial relationships, have been shown to be capable of more accurately estimating energy policy impacts, particularly those resulting from site-specific energy development activities.

The chapter has further discussed three basic frameworks for projecting regional activities: single region econometric, multi-regional econometric, and multiregional input-output models. Single region econometric models, although of considerable sectoral and spatial detail, have been shown to be of limited use because of their failure to recognize the spatial distributions of interregional impact transfers. Multiregional models, on the other hand, have in most cases been found to account for these transfers, but usually at the cost of reduced sectoral and/or spatial detail.

The multiregional models examined in this chapter have been found to vary significantly in terms of structure, spatial detail and comprehensiveness, which suggest several criteria over which they can be evaluated. These include the availability and reliability of supporting data, spatial and sectoral resolution of the model, and the model's structure and policy sensitivity. A further consideration must be the current status of each model, whether in a conceptual, development or operational mode.

The first two criteria specified above (the availability and reliability of supporting data, and the spatial and sectoral resolution of the model) are closely related. Data are far more

complete and reliable at the national level than for any other regional definitions. A general rule of thumb would suggest both the quality and quantity of data to decline as smaller geographical units of analysis are represented in a modeling framework (hence, the top-down approach to modeling, since it requires less regional data).

The Harris model uses the county as the basic spatial unit of analysis; it furthermore disaggregates industrial activity to a fine level of detail: industrial economic indicators are forecast at the 3- and 4-digit SIC levels. The NRIES, MRIO and Chase models, on the other hand, spatially disaggregate only to state geographic units (although the latter disaggregates to SMSA's as well). Although the MRIO model is industrially detailed, the NRIES and Chase models are relatively aggregate, sectorally as well as spatially, characterizing industrial activity at only the 1- and 2-digit levels, respectively. The Brookhaven linear programming multiregional input-output model is very aggregate, considering only nine regions and 30 industrial categories.

Although theoretically attractive, increasing spatial and sectoral disaggregation places greater demands upon the data which may be beyond the information content of current data bases. For example, county-level data for the Harris model is, in many instances, constructed or estimated, which can introduce additional error into the model's specification. Although the developers of county-level models have confidence in the data used to estimate them, and although continuing development of one of these models will involve further disaggregation to the sub-county level (Harris, 1978), there is some consensus among economists that currently, the most disaggregate data of sufficient reliability and consistency are state-level (Bolton, 1979). But these contentions are far from resolved. However, it should be noted that peer review of the county-level READ model, recently undertaken at the request of DOE, concluded that county data were not likely to be reliable enough to support parameter estimates in the model. In view of this finding, it is appropriate to undertake regional

analyses at more aggregate levels of resolution, realizing, however, that such an approach may limit the range of phenomena which can be investigated. Only multiregional energy policies or facility development decisions which generate large direct impacts should be subject to analyses through these more aggregate modeling frameworks.

Structural characteristics of multiregional models have been shown to affect both their simulation behavior and the degree to which they can be considered interregional. Recursive model structures such as those employed in the Harris and Chase models tend to be more flexible policy analysis tools since exogenous variables are well specified in each equation, and a direct causal sequence of economic events can be inferred from the recursive structure (Simon, 1957). Similarly, multiregional input-output models, despite their formally defined structure, are capable of addressing a variety of policy issues through the manipulation of regional final demand vectors. Since final demand is essentially assumed to be exogenous to the regional economic system, direct causal linkages can be established between policy initiatives (primarily facility development decisions) and subsequent economic impacts. As structural relationships between industrial and demographic sectors and regions become more simultaneous, however, the simulation of policy alternatives becomes more difficult since fewer exogenous variables exist to be adjusted. Instead, ad hoc and internally inconsistent overrides must often be input into the system to incorporate policy, which adds an additional element of error into the model's forecasts.

However, only through the simultaneous structuring of relationships among regions can the interregional transmission of impacts truly be modeled. The definition of lagged relationships is dependent upon exogenously specified interregional product flows in the recursive framework of the Harris model leaving the interregional transmission of impacts implicit rather than explicit. By not recognizing the direct interdependencies between regions, the recursive structure thereby overlooks an important transmitter of economic impacts.

Note, however, that at least some of the interregional impact flows are being accounted for by the Harris model through lagged endogenous relationships which affect producer's location decisions in later time periods. But the degree to which these relationships capture spatially diffuse economic impacts can only be speculated. The Chase model, on the other hand, is currently incapable of addressing interregional impact issues since appropriate simultaneous or lagged relationships between regions do not exist. Of the econometric frameworks, only the BEA NRIES model is currently structured to recognize the simultaneous nature of economic and demographic relationships between regions. Since the interregional structure of the national economy is explicitly recognized by multiregional input-output models, transmission of impacts among regions is effectively portrayed in this framework. Note that in this latter case, the spatial distribution of impacts from policy decisions is dependent upon historical data manifested in trade flow coefficients. No explicit behavioral bases govern the allocation of impacts among regions which is in contrast to economic potential or gravity relationships assumed in the NRIES framework.

Finally, the current status of each of the models discussed above serves as a useful criterion of evaluation. The Harris and MRIO models have been operational for several years and have been successfully applied in several contexts (see Harris, 1974; Krutilla et al., 1978; Golladay and Haveman, 1977). The Brookhaven multiregional linear programming model has seen limited application, and the Chase regional model, although undergoing continual development, is operational. The development of the NRIES model has recently been completed and the model is currently undertaking policy simulations and test runs (Ballard and Wendling, 1978). Another major multiregional modeling effort by Wharton Econometric Forecasting Associates, Inc. (WEFA) for the Electric Power Research Institute will not be completed until 1980.¹

The significant characteristics of the econometric multiregional modeling frameworks reviewed in this chapter are shown in Figure 3-5. Although brief, the table essentially displays the trade-offs between multiregional modeling frameworks. The ultimate choice must

¹Personal communication from Colin J. Loxley, Wharton Econometric Forecasting Associates, Inc.

Figure 3-5

Summary of Characteristics of Multiregional
Econometric and Input-Output Models

	Harris (1973)	Chase (1978)	NRIES (1978)	MRIO (1970)	Brookhaven (1977)
Basic Model Structure	recursive	recursive	simultaneous	input-output	input-output linear programming
Spatial Detail	county	state and SMSA's	state	state	Census divisions
Sectoral Detail	99 industrial sectors (3 and 4 digit SIC)	up to 20 industrial sectors (2 digit SIC)	13 industrial sectors (1 digit SIC)	79 industries	30 industries
Impact Sensitivity	primarily intraregional	exclusively intraregional	intra and interregional	intra and interregional	intra and interregional
Policy Instruments	exogenous variables	exogenous variables	equation overrides/ exogenous variables	final demand vector	final demand vector/ LP constraints
Status	operational	operational	operational	operational	operational

depend upon the context in which the model is to be applied.

The multiregional econometric framework embodied in NRIES is a unique departure from other multiregional modeling efforts. Its bottom-up structure, where regional economies are less dependent upon national economic activity, provides a potentially sensitive policy instrument for assessing impacts attributable to capital investment activities in states. (As suggested above, it is less appropriate for estimating impacts from multiregional pricing and allocation policies.) Because of this potential, and because NRIES is relatively untested outside of BEA, DOE has chosen to evaluate the model further by incorporating it into the DREEM framework to assess regional impacts of selected energy policy decisions which are representative of those likely to be considered by the Agency in the future.¹

Given the nature of economic development activities being addressed, the application of NRIES to the analysis of their impacts can be justified since substantial interregional transfers can be expected, particularly in those regions possessing poorly developed economic and demographic infrastructures. Since the model is relatively aggregated sectorally, however, interregional impact analyses should address only large-scale energy development activities, such as alternative coal mining and processing scenarios, OCS leasing, state-level electricity generation scenarios, etc. Single facility site-specific impacts are not of the appropriate scale to be addressed by this model since the interregional transmissions of impacts from single facility development are likely to be miniscule compared to total interregional trade flows. Interindustry transactions within the region and other intraregional phenomena are more important for this scale of development and may be better addressed by single region econometric models developed specifically for that purpose or by more spatially and sectorally detailed models such as the Harris and Chase models described above.

¹Part of NRIES' development was funded by DOE.

The remainder of this report concerns the evaluation of NRIES as a DREEM candidate. However, it is a partial one in that it considers the suitability of NRIES for estimating policy impacts only in terms of input requirements and model structure. The report does not analyze scenario outputs (regional impact estimates). Outputs from scenario runs have been analyzed and documented in a separate report to DOE by developers of NRIES at BEA.

The evaluation proceeds as follows in the next chapter. First a number of potential policy scenarios are suggested and briefly discussed. The suitability of NRIES for incorporating these scenarios into model forecasts is then assessed from which a subset of scenarios are proposed for further analysis. These scenarios are chosen to exhibit the variation in policy issues which NRIES is potentially capable of addressing. More detailed specification of input requirements for reflecting policy scenarios and development of input data follow.

Application of a DREEM Framework4.0 Introduction

Simulation of regional impacts of energy policy scenarios through NRIES is accomplished either by adjusting exogenous national variables in the model, or, if the direct impacts are spatially defined, by adjusting appropriate state-level output variables over the policy impact period. Indirect and induced impacts are then identified by comparing "perturbed" model forecasts with an a priori established baseline forecast. Currently, NRIES forecasts to the year 1985 from a 1977 base year and impact assessments to be undertaken in this study must necessarily be restricted to this time frame.

Since the number of exogenous variables in the model is few, most analyses using NRIES can be expected to require state-level adjustments to selected industrial sectors. And similar to other multiregional models, the specification of changes to NRIES to reflect policy impacts requires considerable effort, particularly when dealing with multi-state policies, to ensure that appropriate functional and geographical detail is incorporated into forecasts. For example, to assess the economic and demographic impacts of accelerated outer continental shelf (OCS) development, inputs to the model would have to be identified by directly impacted industrial sector, such as mining or contract construction, and by state. To formulate these inputs, then, preliminary analysis would be required to geographically allocate direct impacts either by use of other models, on the basis of historical data or on the basis of information from, say, the petroleum exploration industry. In many cases, the analytical requirements for formulating inputs to multi-regional models are as formidable as the models themselves, but for an important reason. Errors at this stage of the analysis can totally invalidate regional impact estimates made by the multiregional model.

It should also be noted that NRIES' estimates of indirect and induced impacts are susceptible to error through adjustment procedures used to characterize sub-national policy scenarios.

Because the model is highly simultaneous, few techniques for changing state output levels are available. Granger and Newbold (1977, p. 199) note that, in general, adjustments to individual equations in simultaneous models to reflect exogenous shocks to the system must usually involve either setting non-zero values for the error terms in affected equations or, equivalently, adjusting the constant terms. Since no rigorous quantitative framework for determining these adjustments exists in economic theory, constant or error term adjustments must necessarily be judgemental, and usually require considerable advance work and familiarity with the model to effect reasonable changes to appropriate equations (Bolton, 1979, p.58). Furthermore, such adjustments typically introduce consistency problems as they explicitly override assumed structural relationships in the model (see p. 23). Both the judgemental adjustment procedures and inconsistencies in structural relationships which result can thus be expected to introduce some error into impact estimates associated with energy policy scenarios. The extent to which NRIES' forecasts are influenced by these errors, however, can only be subjectively assessed.

In spite of the aforementioned problems of input data specification and model adjustment, NRIES, on the basis of its bottom-up structure, provides a unique analytical framework for assessing the regional impacts of energy policy decisions, and it is the purpose of this chapter to demonstrate the feasibility of the model for undertaking energy-related impact assessments by developing a set of scenarios and supporting data which can be simulated through the multiregional modeling framework. Since resources for accomplishing this task are limited, the objective of the chapter is to develop a set of scenarios which economically demonstrates the range of capabilities which NRIES possesses for analyzing policy impacts.

To achieve this, a larger group of scenarios is first reviewed and analyzed in this chapter in the context of NRIES' strengths and weaknesses. These scenarios evolved initially from discussions with DOE and BEA personnel and were subsequently defined more precisely in follow-up analyses. An outline of these

scenarios and the utility of NRIES for analyzing their expected impacts is presented in Section 4.1. From this initial set, three scenarios are chosen for application to NRIES: a Montana Coal scenario, a Data Resources, Inc. (DRI) Macroeconomic scenario, and the Administrator's Annual Report (AAR)¹ National Energy scenario. Following a discussion of reasons for choosing these scenarios, the chapter describes each in more detail so that data inputs to NRIES can be more precisely defined.

4.1 An Evaluation of Potential Scenarios for Analysis by NRIES

A total of seven scenarios or scenario sets were originally considered for implementation in the NRIES/DREEM framework. These scenarios are identified by the following acronyms.

- o Montana Coal
- o Ohio Coal
- o NEEPA 1
- o National Coal Strike
- o AAR Coal
- o AAR National Energy
- o DRI Macro.

Montana and Ohio Coal scenarios are essentially single-state scenarios; NEEPA 1, National Coal Strike and AAR Coal scenarios are multi-state; and the DRI Macro scenario is a purely national scenario. The AAR National Energy scenario is slightly more complex than the others as it embodies both national and multi-state policy impacts. Each of these scenarios is briefly outlined below.

4.1.1 Scenario Descriptions

Montana Coal Scenario

The Montana Coal scenario is actually a set of four scenarios which depict alternative coal and coal-related development strategies for Rosebud and Big Horn counties in Montana. They have been adapted from a recent study undertaken by Resources for the Future (RfF) to assess economic, demographic and fiscal impacts expected in the

¹This report is now referred to as the Annual Report to Congress (ARC).

two counties over the 1975 to 1990 period.

The first scenario of this set represents a "base case" which maintains coal production in the state at approximately its 1977 level and postulates no construction of energy facilities between 1977 and 1985. (Two 350MW power plants were completed at Colstrip, Montana in 1975 and 1976.) The second scenario reflects best estimates for future coal development in the two counties based upon prospects or plans of the coal industry. This scenario postulates an additional 38 million tons of annual production over the first scenario by 1982. A third scenario represents a substantially larger increase in production, consistent with the National Energy Plan goal of energy self-sufficiency. The scenario adds six new ten million ton per year mines in the two counties beginning in 1977. Construction on the last mine is assumed to commence in 1981. The final scenario involves the same increase in coal production as the previous one, but also includes the construction and operation of two coal-fired power plants and a coal gasification facility. Construction of the first power plant is assumed to begin in 1977, and the second in 1979; they are completed in 1982 and 1984, respectively. Full scale power production by the plants is expected in 1983 and 1985. Construction of the gasification plant is assumed to begin in 1981 and end in 1984 with the plant coming on-line the following year.

Ohio Coal Scenario

Analysis of this scenario is intended to estimate the spatial and temporal impacts expected to be associated with a recent ruling by the Environmental Protection Agency (EPA) concerning sulfur dioxide limitations specified in EPA's proposed State Implementation Plan (SIP) for Ohio. The ruling states that most Ohio utilities must be in compliance with their respective SO₂ emission limitations by October, 1979. To meet these limitations, these utilities must either burn coal with lower sulfur content than currently being used or install flue gas desulfurization equipment (scrubbers).

Most utilities indicated at the time that they intended to replace some portion or all of their Ohio coal purchases with low-sulfur coal, principally from Central Appalachia. Figures indicate that a shift from Ohio coal by 14 major utilities in the state would cut production of Ohio coal by 15.8 million tons per year by 1980, or 33.7 percent. Most replacement coal would come from eastern Kentucky and West Virginia. Purchases of high-sulfur coal by Ohio utilities from Indiana, Pennsylvania, West Virginia and Maryland would also be cut, reducing their production from 0.1 to 1 percent. These direct impacts are hypothesized to be sustained over the 1980 to 1985 forecasting period of the model.

NEEPA 1 Scenarios

NEEPA 1 scenarios are taken from a study conducted by the Massachusetts Energy Office for the U.S. Department of Energy and the New England States to determine the potential economic impacts of energy conservation and alternative energy development scenarios over the 1975 to 1985 period and beyond.¹ In all, six scenarios are drawn from this study for consideration:

- o Outer Continental Shelf (OCS)--High find
- o OCS--Medium find
- o OCS--No-find
- o Coal-fired base load plant (800MW)
- o Nuclear power plant construction (1194MW)
- o Energy conservation

The OCS scenarios consider exploration and development of potential off-shore oil and gas reserves in Georges Bank commencing in 1978 (assuming a 1977 lease sale) and continuing for between 15 (for the No-find scenario) and 30 (High find scenario) years. The High find scenario assumes 2.4 billion barrels of oil and 12.5

¹See The Commonwealth of Massachusetts, NEEPA 1: The New England Policy Alternatives Study, Final Report for the Department of Energy and the New England States, Massachusetts Energy Office, Boston, MA, October (1978).

trillion cubic feet of natural gas to be commercially exploitable. Peak exploration activity is assumed to occur between 1984 and 1986 and peak production between 1997 and 2003 (440,000 bbl/day). Nearly \$3.5 billion in capital investment for onshore facilities, primarily pipelines and a refinery, is assumed in this scenario.

Under the Medium find scenario, 900 million barrels of oil and 4.2 trillion cubic feet of natural gas are expected to be commercially exploitable from Georges Bank. Exploration activity is assumed identical to the High find scenario, but production, estimated to begin in 1988 is assumed to peak at 166,000 bbl/day between 1994 and 2003. Capital investment is assumed to approach \$1 billion, primarily in gas pipelines; no refinery is hypothesized for this scenario. Whereas the High find scenario assumes direct employment impacts averaging 2,800 workers per year, direct employment impacts in the Medium find scenario are expected to average slightly more than 700 workers.

In the No-find scenario, no commercially exploitable reserves are found. The scenario is characterized by limited exploration which ends in 1984 and little on-shore development of bases. Less than \$1 million is invested in capital equipment and direct employment impacts which peak in 1978 average 133 workers per year over the 6-year period.

The coal-fired base load generating plant scenario concerns the construction and operation of the planned 800-1,000MW Sears Island plant in Maine. All impact estimates in the study relate to 800MW capacity. Construction is assumed to require 5 years and is expected to terminate in 1983. The nuclear power plant scenario assumes one 1,194MW plant coming on-line in 1984 after a seven-year construction period. Although no specific location for the plant is described in NEEPA 1 documentation, it is likely to be either Rhode Island or Massachusetts.

The energy conservation scenarios examined in this study are the most comprehensive energy policy scenarios analyzed and involve several levels of conservation in the residential, commercial and

industrial sectors in New England. Two conservation alternatives are assumed in the commercial sector. The first applies ASHRAE 90-75 standards¹ to new commercial buildings constructed between 1979 and 1985. A 40 to 50 percent reduction in energy use is assumed achieved with no net increases in building construction costs. (Some increase in construction labor employment is assumed, however.) The second conservation level assumes retrofitting existing commercial buildings in addition to measures in the first level, achieving a 20 percent reduction in energy consumption in these older establishments. Two residential conservation scenarios involve different assumptions about insulation and weatherization. The first assumption achieves a 20 percent, and the second a 30 percent reduction in energy consumption from the residential sector. Industrial establishments are assumed to achieve only a 16 percent reduction in energy consumption by 1985 in all scenarios.

National Coal Strike Scenario

The National Coal Strike scenario is intended to test NRIES' analytical capabilities for evaluating regional economic impacts of a major work stoppage in the coal industry similar to that which occurred in the winter of 1978. The scenario is therefore designed to reflect losses in coal mining output, manufacturing and non-manufacturing output and electrical generation attributable to the strike. States directly impacted in the scenario are Indiana, Kentucky, Michigan, Ohio, West Virginia and Pennsylvania. Historical data from 1978 are expected to provide requisite information for defining direct impacts.

AAR Coal Scenario

This scenario is designed to test NRIES' capabilities for estimating the regional impacts of coal production projections forecast by U.S. DOE in its Annual Report to Congress (U.S. DOE, 1978). Coal production projections for 1985, which are part of a comprehensive series of conditional forecasts of energy supply and demand based on alternative policy, pricing and investment

¹American Society of Heating, Air Conditioning and Refrigeration Engineers (ASHRAE), Energy Conservation in New Building Design, ASHRAE 90-75, New York (1975).

assumptions, are generally higher than extrapolations of current trends in the industry.

The AAR Coal scenario, which represents just one of these conditional forecasts, assumes the production of 1,058 million tons of coal annually by 1985 (Wendling and Ballard, 1979) corresponding to the "medium demand--medium supply--high oil price" scenario in the Annual Report. The regional dispersion of coal mining growth is also assumed to change from historical trends in the scenario to one which conforms more closely to known coal reserves in the states. Fifteen states are assumed to be directly impacted by the forecast, experiencing investment and production increases over the 1978 to 1985 time frame.

AAR National Energy Scenario

The AAR National Energy scenario is intended to take a more comprehensive approach to estimating impacts from energy forecasts developed by DOE. The scenario is essentially a translation of energy supply estimates for 1985 from a selected Midterm Energy Forecasting System (MEFS) (formerly PIES) scenario into annual capital and operating direct impacts to state economies. Energy sectors involved include coal, oil and gas development, petroleum refining, synthetic fuel production, electricity generation and transportation of energy products. Macroeconomic parameters are also adjusted to correspond to values assumed in the macroeconomic driver of MEFS.

DRI Macroeconomic Scenario

This "scenario" is more a test to determine whether NRIES, which generally relies on macroeconomic estimates generated by the BEA macroeconomic model, can accommodate economic parameters forecast by the Data Resources, Inc. (DRI) macroeconomic model. The latter model is widely used within EIA and forms the bases for several modeling efforts (including MEFS) currently undertaken there. This scenario is purely a national one. It requires the substitution of values of national economic variables generated in a selected DRI forecast for equivalent variables forecast by

the BEA macroeconomic model which are input as exogenous variables into the NRIES modeling framework. Substitution is undertaken for each year forecast by NRIES.

4.1.2 Scenario Evaluations

Although each scenario presents interesting possibilities for analysis, resource limitations preclude the development of inputs for all but a subset of those outlined above. To define this subset, we can establish a set of criteria by which to evaluate scenarios in the context of developing an appropriate DREEM framework.

- o Can the scenario be reasonably incorporated into NRIES? Apart from technical problems in adjusting equations to incorporate impacts, scenarios must reasonably conform to the levels of functional and spatial aggregation in the model, to its forecasting horizon (1985) and temporal increment (one year). Scenarios should be oriented towards output impacts rather than price impacts since NRIES essentially excludes prices from its structure.
- o Are the data accessible? Scenarios which require proprietary data or require excessive transformations of existing data to make them compatible to NRIES variable definitions are likely to be less informative than others since the data inputs can be expected to contain significant error. The further removed NRIES' input data are from their source (the energy policy itself), the less accurate will be model forecasts.
- o Does the scenario contribute to the objectives of the study? A major objective of this research effort is to demonstrate the range of energy-related policies which can be incorporated into NRIES. This would suggest that one scenario should be chosen from each geographic level: state, multi-state, and national.
- o Does the scenario have any special policy relevance to DOE? Although all scenarios outlined above relate to energy policy and impacts, some may be more significant in terms of DOE's mandate, or may simply demonstrate new analytical capabilities which are required in the Agency.

Each of these criteria are explicitly or implicitly considered in the following analysis.

State-level scenarios are the most easily implemented scenarios for NRIES. In both the Montana Coal and Ohio Coal scenarios, direct

impacts are input to the model by adjusting appropriate output sectors in the impacted states. In the Montana Coal scenario, adjustments to sectors are required only in the state of Montana; interjurisdictional spillovers of direct impacts in the Ohio Coal case require some adjustments in the mining and transportation sectors of Pennsylvania, Maryland, West Virginia, Indiana and Kentucky. As such, the latter is not truly a single-state scenario. Data for developing direct impacts for both scenarios are available from previous studies.¹

Clearly, the scenarios examine totally different policy issues. The Montana Coal scenario deals with capacity expansion and capital investment; the Ohio Coal scenario concerns reallocations of capital and materials flows. Although both issues are interesting, the former is recommended for analysis by NRIES since it is more relevant to DOE concerns; the Ohio Coal scenario is a matter of EPA policy and although analysis through NRIES might provide additional insight into likely regional and interregional impacts, it is not considered further in this study.

Multi-state scenarios are more difficult to transform into appropriate direct impact estimates and several scenarios proposed in this chapter can be judged impractical for application to NRIES. For example, scenarios adapted from NEEPA 1 have been eliminated for several reasons.

OCS scenarios have been considered infeasible for application to NRIES because of the model's short time span. NEEPA 1 considers all Georges Bank exploration and/or development to begin in 1978 (assuming a 1977 lease sale) and to last between 15 (for the No-find) and 30 (for the High find) years. Even if exploration was to begin

¹For the Montana Coal scenario, data sources can be identified in J. Krutilla et al., Economic and Fiscal Impacts of Coal Development: Northern Great Plains, Baltimore: Johns Hopkins University Press, 1978; direct impact data for the Ohio Coal scenario are contained in two reports--Ohio Section 125 Study: Regional Economic Impact Analysis, prepared for U.S. EPA by Temple, Barker and Sloan, Inc., December 1978; and Draft Final Report. Potential Impacts on the Ohio Coal Market: Ohio Utility Compliance With Applicable Air Emission Limitations, submitted to Office of Planning and Evaluation, U.S. EPA, by ICF Inc., December, 1978.

in 1978, no more than half the direct impacts for any scenario could be input to NRIES because the model forecasts only to 1985. Furthermore, leasing is now expected to take place in November, 1979 (barring any more injunctions), which would imply that only five years of direct impacts could be modeled; and the first few years of impacts are likely to be less significant than the subsequent years.

The energy conservation scenario, although extremely interesting, also does not appear suitable for analysis by NRIES. The problem here relates to sector aggregation. The direct investment impacts of conservation expenditures affect two sectors of industrial activity in NRIES--construction and manufacturing. Construction would be the most significantly impacted--the manufacturing sector would be directly impacted only to the extent that homeowners and business-people retrofit existing establishments with conservation devices without contracting the construction sector for services.

Even if we assume this latter event to be insignificant, problems in attempting to accurately gauge economic relationships in the region can be anticipated when we adjust the value-added term in the construction equation. Presumably, the value-added in manufacturing is directly related to the value-added in construction, from whence we can determine an indirect impact. But conservation devices are specialized goods within the manufacturing sector, and the relationship between a change in value-added in construction due to higher conservation expenditures and the change in value-added in the conservation device manufacturing sector is likely to be totally different to the relationship between value-added in all construction and value-added in manufacturing, the latter of which is the relationship currently embodied in NRIES. Over the past 20 years, conservation expenditures by the construction sector have not played as significant a role as they are likely to play in the future. If we use NRIES to model a conservation scenario, there is no way to capture the shift in conservation expenditures by construction; sector definitions are simply too gross. Because of this, neither the indirect impacts related

to sector outputs, nor the indirect impacts reflecting energy conservation (decreases in utility output, construction, etc.) are expected to be adequately accounted for by the model.

The remaining two scenarios, relating to construction and operating impacts of coal-fired and nuclear power plants in New England, respectively, can be analyzed by NRIES since they are construction oriented and site-specific. However, these scenarios do not demonstrate any capabilities of the model beyond those likely to be exhibited in the Montana Coal and Ohio Coal scenarios.

The National Coal Strike scenario is similarly one beyond the capabilities of NRIES to model. Problems here relate to data availability and more fundamental problems concerning structural and temporal relationships in the model. With respect to the former, 1978 data on manufacturing and non-manufacturing output by state were not yet available from the Department of Commerce at the time of this study. Furthermore, a survey of impacted states to determine whether similar data were available from state agencies was similarly unsuccessful. Most states rely upon the Department of Commerce to supply them with output data. Output data could be estimated from employment data from states (Kendrick and Jaycox, 1965), but consistency problems would likely exist.

The more fundamental problem, however, in developing appropriate inputs for this scenario is how to translate a 3-month phenomenon (the coal strike) into an annual one, which NRIES requires. The direct impacts of the strike were mostly related to electrical generation cutbacks due to the coal shortage, which impacted production levels, etc. Total annual output from the utilities sectors, then, would be lower than under normal economic conditions. However, other production sectors are not necessarily going to show the same depression in output levels, simply because they may use inventories to fill the gap left by reduced outputs over the cutback period. Furthermore, production losses can be made up by producing "overtime" over the remainder of the year.

These fluctuations are simply beyond the capabilities of NRIES to account for both because its time scale is too aggregate

and because the model does not consider inventories, etc., in its structure. Thus, NRIES appears inappropriate for analyzing the regional economic impacts of the 1978 coal strike.

The remaining multi-state scenarios concern analysis of elements of the EIA's Annual Report to Congress. These scenarios are intended to determine the regional and multi-regional economic impacts of alternative energy demand and supply forecasts generated by EIA's Midterm Energy Forecasting System (MEFS) by translating marginal capacity additions by energy supply technology (over a baseline trend) into capital and value-added terms appropriate for input into NRIES. The difference between scenarios relates to comprehensiveness. Whereas the AAR Coal scenario estimates impacts associated with coal production figures in one forecast, the AAR National Energy scenario attempts to assess the impacts associated with production changes in all energy supply technologies forecast by MEFS.

Several problems may be anticipated during the development of data for these scenarios. One relates to the mapping of energy supply sectors in MEFS into appropriate industrial sectors in NRIES. A second problem concerns the translation of MEFS regional forecasts into state-level inputs for NRIES. With regard to this latter problem, each energy product in MEFS has its own corresponding regional definitions which are typically multi-state. And although the geographical units for several sectors, such as petroleum refining and electric utilities, are aggregations of states, regions for other supply sectors, such as coal, oil and gas, are not. Since direct impact inputs to NRIES must be specified at the state level of detail, techniques must be developed for allocating regional supply estimates to state estimates. A third problem is in translating physical or energy units forecasts as they appear in MEFS into appropriate value-added (dollar) terms for NRIES. Here, annual real prices of energy products must be estimated for converting physical output to dollar output which must then be translated to value-added.

Clearly, the amount of data which must be manipulated to develop appropriate state-level inputs is enormous. In the AAR Coal scenario, fifteen states are expected to be directly impacted; in the AAR National Energy scenario, potentially every state in the U.S. can be expected to be directly impacted to some extent over the projection period. Estimation of direct impacts for input to NRIES can therefore be expected to be a non-trivial task. But given that regional analysis capabilities within EIA for assessing impacts associated with alternative MEFS forecasts are currently limited to the REIS modeling framework, an evaluation of NRIES' capabilities for providing greater regional detail would appear particularly relevant to this research effort. Since BEA has recently analyzed the AAR Coal scenario in a separate study (see Wending and Ballard, 1979), this report attempts to develop a design for estimating state-level direct impacts associated with the AAR National Energy scenario which can be input to the NRIES.

The national scenario proposed for DREEM is a straightforward one. "Direct impacts", which are simply the relevant parameters of an alternative macroeconomic forecast, are incorporated into the model by substituting DRI projected variables for equivalent BEA macro variables in the "exogenous national variables" component of NRIES. The scenario is relevant for determining consistency between NRIES and DRI forecasts. Since NRIES is a bottom-up econometric framework, its forecasts are not tied to national control totals and thus consistency between most economic variables projected by its macroeconomic "driver" and equivalent national variables in NRIES, which can be derived by aggregating state-level final demand and output estimates, is not assured. DRI macroeconomic forecasts are "official" projections used by EIA for analysis purposes and it is therefore important to maintain consistency between national and regional projections. This is particularly true in the attempt to link MEFS energy forecasts to NRIES, as macroeconomic parameters used to drive MEFS are supplied by DRI. Substitution into NRIES of selected DRI macroeconomic variables for BEA macroeconomic variables provides at least some degree of consistency, but does not guarantee total agreement between forecasts. It is important

to determine whether variable substitution effects significant changes in NRIES' state forecasts and to measure the major differences between aggregated state-level parameters in NRIES and equivalent national ones in the DRI forecast used to drive the model.

Scenarios chosen for further development in this study are thus the following.

- o Montana Coal Scenario
- o AAR National Energy Scenario
- o DRI Macroeconomic Scenario

Combined, they represent state, multi-state and national policy scenarios and therefore provide the required range of applications necessary for demonstrating NRIES impact assessment capabilities. The following sections outline research efforts undertaken to develop appropriate input data for each of the chosen scenarios.

4.2 Montana Coal Development Scenarios

Coal development scenarios for the state of Montana were originally conceived for an RfF study on construction and operating impacts likely to be experienced in the host counties of Rosebud and Big Horn (see Krutilla et al., 1978). (The intention was originally to replicate the RfF scenarios to compare regional impact estimates.) However, some revisions to the original RfF scenarios were required to make them compatible with the NRIES framework. This was necessary because the forecasting horizon of NRIES extends from 1978 to 1985 rather than from 1970 as in the case with the Harris model, which was used in the RfF study. Given the one-year lag relationships in the model, this meant that scenarios may only be defined from 1977 in NRIES and thus some updating of the 1975 base in the RfF study was necessary. Furthermore, the RfF scenarios extend five years beyond the current forecasting horizon of NRIES which required either the truncation of direct impacts beyond 1985 or the redefinition of the phasing of energy-related development within the 1977-1985 period.

Before arbitrarily redefining the RfF scenarios, both Rosebud and Big Horn counties were surveyed to determine how much coal mining development was actually expected over the next few years. Planned coal mining capacity additions are shown in Table 4-1. The survey revealed less additional production anticipated than most of the RfF scenarios and significantly altered timing of coal mining development. Given the substantial differences between reality and the RfF scenarios, the replication of these scenarios by NRIES loses much of its significance. As a result of these findings, the three RfF scenarios have been substantially altered to define the direct impacts due to energy development activities for NRIES.

Scenario I (which is identical to RfF) calls for no additional development of coal production beyond 1977 levels over the forecasting period. This scenario is essentially accounted for in current NRIES outputs. Scenario IIa reflects current development expectations as represented in Table 4-1.¹ The Consolidated Coal Co. venture in Bug Horn County is expected to be in operation by 1982 to produce 10 million tons annually; Montco Coal Co. is assumed operating in 1981 and to produce 12 million tons annually. Scenario IIIa essentially delays the RfF Scenario III development schedule by two years to conform to the input requirements of NRIES. Thus, six ten million ton mines are constructed over the forecasting period, with construction commencing on one mine in 1977, two in 1978, and one each in 1979, 1980 and 1981. Scenario IVb assumes the same staging of coal mining development as IIIa but includes the construction of two coal-fired power plants and a coal gasification facility. Construction of the first power plant is assumed to commence in 1977 and terminate in 1982; the second plant is constructed between 1979 and 1984. Electricity is assumed generated at each of the 2600 MW facilities in the first year following its completion. The gasification plant is constructed between 1981 and 1984, and is assumed to produce gas at the rate of 250 million cubic feet per day (capacity) in 1985. These scenarios are illustrated in Table 4-2.

¹The scenario identification scheme used above was designed to distinguish scenarios from the RfF ones from which they were derived.

Table 4-1

Anticipated Coal Mining Development In
Big Horn and Rosebud Counties

<u>Company Name or Other Identifier</u>	<u>Construction</u>	<u>Operation</u>	<u>Annual Output (million tons)</u>
<u>Big Horn County</u>			
East Decker Coal Co.	N/A	1977	4
Shell Mine	N/A	1979	2
Spring Creek	N/A	1979	10
Consolidated Coal Co.	N/A	N/A	N/A
<u>Rosebud County</u>			
Montco Coal Co.	1980-81	1981-82	5-12

N/A = not available

Table 4-2
ALTERNATIVE SCENARIOS DEVELOPED FOR NRIES

Scenario	1977	1978	1979	1980	1981	1982	1983	1984	1985	Location (county)
I	--	--	--	--	--	--	--	--	--	
IIa Construction ¹	M-1(4)	M-1(4) M-2(2) M-3(10)	M-1(4) M-2(2) M-3(10)	M-1(4) M-2(2) M-3(10) M-4(12)	M-1(4) M-2(2) M-3(10) M-4(12) M-5(10)	M-2(2) M-3(10) M-4(12) M-5(10)	M-2(2) M-3(10) M-4(12) M-5(10)			Big Horn Big Horn Big Horn Rosebud Big Horn
Operation ²	M-1(.036)	M-1(.65)	M-1(2) M-2(.018) M-3(.09)	M-1(2.6) M-2(.32) M-3(1.6)	M-1(4) M-2(1) M-3(5) M-4(.108)	M-1(4) M-2(1.3) M-3(6.5) M-4(1.9) M-5(.09)	M-1(4) M-2(2) M-3(10) M-4(6) M-5(1.6)	M-1(4) M-2(2) M-3(10) M-4(7.8) M-5(5)	M-1(4) M-2(2) M-3(10) M-4(12) M-5(6.5)	
IIIa Construction ¹	M-1(10)	M-1(10) M-2(10) M-3(10)	M-1(10) M-2(10) M-3(10) M-4(10)	M-1(10) M-2(10) M-3(10) M-4(10) M-5(10)	M-1(10) M-2(10) M-3(10) M-4(10) M-5(10) M-6(10)	M-1(10) M-2(10) M-3(10) M-4(10) M-5(10) M-6(10)	M-2(10) M-3(10) M-4(10) M-5(10) M-6(10)			Rosebud Rosebud Big Horn Rosebud Big Horn Rosebud
Operation ²		M-1(.09)	M-1(1.6) M-2(.009) M-3(.09)	M-1(5) M-2(1.6) M-3(1.6) M-4(.09)	M-1(6.5) M-2(5) M-3(5) M-4(1.6) M-5(.09)	M-1(10) M-2(6.5) M-3(6.5) M-4(5) M-5(1.6) M-6(.09)	M-1(10) M-2(10) M-3(10) M-4(8.5) M-5(5) M-6(1.6)	M-1(10) M-2(10) M-3(10) M-4(10) M-5(6.5) M-6(5)	M-1(10) M-2(10) M-3(10) M-4(10) M-5(10) M-6(6.5)	
IVb Construction ³	(Mine Construction Identical to IIIa)									Rosebud Rosebud Big Horn
	U-1(2600)	U-1(2600)	U-1(2600) U-2(2600)	U-1(2600) U-2(2600)	U-1(2600) U-2(2600) G-1(250)	U-1(2600) U-2(2600) G-1(250)	U-2(2600) G-1(250)	U-2(2600) G-1(250)		
Operation ³	(Coal Production Identical to IIIa)									
							U-1(2600)	U-1(2600)	U-1(2600) U-2(2600) G-1(250)	

¹ Assumes construction schedule as in Table 4-4; numbers in parentheses are annual production capacities (10⁶ tons)..

² Assumes operation schedule as in Table 4-4; numbers in parentheses are annual production outputs (10⁶ tons).

³ Assumes construction and operation schedules as in Tables 4-3 and 4-5; numbers in parentheses are capacities.

M=Mine
U=Coal fired power plant
G=Coal gasifier

4.2.1 Sources of Data for Quantification of Direct Impacts

Although the RfF study provides a convenient resource as a data base, much of these data are confidential and cannot be replicated. For this reason the following source (noted as Bechtel (1978) in this document) was used to define direct capital requirements for coal mines and the coal gasification plant:¹

- o Resource Requirements, Impacts, and Potential Constraints Associated With Various Energy Futures by the Bechtel National, Inc., August, 1978.

This source is widely recognized as an excellent source for capital cost data. Tables 4-4 and 4-5 detail capital cost data from Bechtel used to formulate estimates for coal mines and the coal gasification plant. Coal-fired power plant capital cost estimates in Table 4-3 were taken from a study undertaken by United Engineers (1974). These data are the same as those used by Krutilla et al. (1978) in the RfF report. All figures are reported in 1972 dollars to reflect input requirements for NRIES.

4.2.2 Calculation of Direct Impacts

Direct impacts from increased coal mining and construction activity in the state of Montana affect output in up to four economic sectors in NRIES. In all scenarios, coal mining construction and operation affect the contract construction and mining sectors in NRIES, respectively. The construction sector is also further impacted by power plant and gasification facility construction activities in Scenario IVb. Production of electricity from the coal-fired power plants can be expected to impact output in transportation, communications and public utilities in the model and synfuel production is assumed to impact the non-durables manufacturing sector in the scenario.

¹ RfF data for power plant capital costs were identified and utilized in this study (see Table 4-3).

Table 4-3

Capital Costs for a 2600 MW Coal-Fired Power Plant

(two 1300 MW generators with SO₂ removal equipment and natural draft cooling towers)
(all costs in millions of 1972 dollars)

Year	Capital Costs*			
	Total Cost	Construction Sector Cost	Manufacturing Sector Cost	% Constructed in Each Year
1	14.91	6.02	8.89	2.5%
2	44.70	18.05	26.65	7.5%
3	119.11	48.13	70.98	20. %
4	238.22	96.26	141.96	40. %
5	119.11	23.17	70.98	20. %
6	59.55	24.07	35.48	10. %
7 & after	0	0	0	0

*Capital Costs from Power Plant Capital Costs: Current Trends and Sensitivity to Economic Parameters by United Engineers and ORNL (1974). Interest and escalation during construction ignored. Two units constructed simultaneously. Costs deflated to 1972 dollars using BEA GNP deflator. Bechtel (1978) allocates 40.40% of total construction cost to construction sector, remainder to manufacturing sector.

Table 4-4

Capital and Operating Costs for a 10 Million Ton Per Year (tpy) Surface Coal Mine*

(all figures in millions of 1972 dollars)

Year	Capital Cost**					Operations Costs			
	% Constructed***	Materials and Equipment	Manpower	Other Constructors Cost	Other Owners Costs (allocated to materials)	Manpower	Materials and Equipment	Utilities	% Of Total Production Achieved****
1	2.5%	1.05	.31	.24	.19	-	-	-	0
2	7.5%	3.18	.92	.71	.58	.07	.06	.01	0.9%
3	30.0%	12.71	3.68	2.83	2.32	1.22	1.04	.28	16.0%
4	30.0%	12.71	3.68	2.83	2.32	3.70	3.14	.85	48-49%
5	27.5%	11.66	3.37	2.59	2.13	4.92	4.17	1.14	64-65%
6	2.5%	1.06	.31	.24	.19	7.63	6.48	1.77	100%
7 & after	0	-	-	-	-	7.63	6.48	1.77	100%

*Derived from Bechtel (1978) estimates for a 6 million tpy surface coal mine by simply scaling up costs by 10/6. Interest and escalation during construction ignored. Operating and maintenance costs for each year derived by multiplying 10/6 of Bechtel cost by % of output achieved for that year. Costs deflated to 1972 dollars using BEA nonresidential fixed investment (capital costs) and GNP deflator (operating costs).

**Total Capital Cost = Materials and Equipment 42.38 50.10
 Manpower 12.27 21.70
 Other Constructor Cost 9.43
 Other Owner's Cost 7.72

***Estimated.

****Derived from RfF data.

Table 4-5

Capital Costs for a 250 Million Cubic Foot Per Day
Coal Gasification Facility - High Btu Gas

(all figures in millions of 1972 dollars)

Year	% Constructed*	Total Construction Cost** for Each Year	Portion Allocated to Construction*** Sector	Portion Allocated to Manufacturing Sector***
1	10%	74.71	26.97	47.74
2	30%	224.06	80.89	144.17
3	40%	298.70	107.83	190.87
4	20%	149.35	53.92	95.43

*Estimated

**From Bechtel (1978) excluding interest and escalation during construction. Deflated to 1972 dollars using GNP price deflator.

***From assumptions in Bechtel (1978).

Two other direct impacts are estimated for all scenarios. The first relates to materials inputs for the construction of energy facilities. All materials inputs are assumed imported by Montana from the rest of the U.S. Furthermore, rather than diverting capital, these inputs are assumed to be in addition to what ordinarily would be expected to be produced by the economy. National economic activity, measured in value-added, in the durables manufacturing sector is therefore incremented by the total value-added of materials requirements for construction activities assumed in each scenario. A second direct impact calculated for each scenario relates not to scenario development assumptions, but rather to a fundamental change in taxation of coal production enacted by the state in 1975. Since NRIES' coefficients are estimated from 1956 to 1976 data, this change in the state taxation revenue equation is not likely to be adequately reflected in model forecasts. Marginal revenues from the new severance tax (not simply marginal coal production) are therefore estimated for each scenario. Calculations of direct impacts by sector for the three Montana coal development scenarios are summarized below.

(i) Construction Value-Added (All Scenarios): From the schedule developed in Table 4-2 and capital cost data in Table 4-4, the value-added component of capital costs for coal mining over the 1977-85 period can be developed as follows:

For any given mine, M, and year, Y.

Construction

Value-added (M,Y) = (Manpower + Other Constructor Costs)_t x
Capacity of Mine as % of 10 million tpy mine.

t = number of years into construction of mine
at year Y.

Construction

Value-added (Y) = $\sum_M$ Construction Value-added (M,Y).

Value-added by year in construction for the power plants and gasification facility in Scenario IVb can be derived directly from Tables 4-2, 4-3, and 4-5. Direct impacts by year in contract construction in Montana for each scenario are therefore calculated as follows.

Value-added by Facility and Year
(Millions of 1972\$)

Scenario IIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (4) ¹	.65 ²	2.60	2.60	2.38	.22				
M-2 (2)		.11	.33	1.30	1.30	1.19	.11		
M-3 (10)		.55	1.63	6.51	6.51	5.96	.55		
M-4 (12)				.66	1.96	7.81	7.81	7.15	.66
M-5 (10)					.55	1.63	6.51	6.51	5.96
TOTAL	.65	3.26	4.56	10.85	10.54	16.59	14.98	13.66	6.62

Scenario IIIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (10)	.55	1.63	6.51	6.51	5.96	.55			
M-2 (10)		.55	1.63	6.51	6.51	5.96	.55		
M-3 (10)		.55	1.63	6.51	6.51	5.96	.55		
M-4 (10)			.55	1.63	6.51	6.51	5.96	.55	
M-5 (10)				.55	1.63	6.51	6.51	5.96	.55
M-6 (10)					.55	1.63	6.51	6.51	5.96
TOTAL	.55	2.73	10.32	21.71	27.67	27.12	20.08	13.02	6.51

Scenario IVb	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Mining ³	.55	2.73	10.32	21.71	27.67	27.12	20.08	13.02	6.51
U-1 (2600) ⁴	6.02	18.05	48.13	96.26	23.17	24.07			
U-2 (2600)			6.02	18.05	48.13	96.26	23.17	24.07	
G-1 (250)					26.97	80.89	107.83	53.92	
TOTAL	6.57	20.78	64.47	136.02	125.94	228.34	151.08	91.01	6.51

¹Numbers in parentheses are annual coal production capacities.

²Assuming mine M-1 is in the second year of construction (first year ignored).

³As calculated for Scenario IIIa.

⁴Numbers in parentheses are annual production capacities (2600MW power plants and 250 million cubic foot per day gasification facility).

(ii) Mining Value-Added (All Scenarios): Mining value-added accrues from the operation of the mine. From Tables 4-2 and 4-4, incremental production over the baseline scenario can be calculated.

Coal Production by Facility and Year
(millions of tons)

Scenario IIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (4)	.036	.65	2.0	2.6	4.0	4.0	4.0	4.0	4.0
M-2 (2)			.018	.32	1.0	1.3	2.0	2.0	2.0
M-3 (10)			.09	1.6	5.0	6.5	10.0	10.0	10.0
M-4 (12)					.108	1.9	6.0	7.8	12.0
M-5 (10)						.09	1.6	5.0	6.5
TOTAL	.036	.65	2.11	4.52	10.11	13.79	23.6	28.8	34.5
Value of Additional Coal Output (millions of 1972 dollars) ¹	.132	2.379	7.715	16.543	36.995	50.471	86.376	105.408	126.270
Value-added of Additional Coal Output (millions of 1972 dollars) ²	.08	1.38	4.48	9.59	21.46	29.27	50.10	61.14	73.24

Scenario IIIa and IVb	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (10)		.09	1.6	5.0	6.5	10.0	10.0	10.0	10.0
M-2 (10)			.09	1.6	5.0	6.5	10.0	10.0	10.0
M-3 (10)			.09	1.6	5.0	6.5	10.0	10.0	10.0
M-4 (10)				.09	1.6	5.0	6.5	10.0	10.0
M-5 (10)					.09	1.6	5.0	6.5	10.0
M-6 (10)						.09	1.6	5.0	6.5
TOTAL	0	.09	1.78	8.29	18.19	29.69	43.10	51.50	56.5
Value of Additional ¹ Coal Output (10 ⁶ 1972\$)	0	0.329	6.515	30.341	66.575	108.665	157.746	188.490	206.790
Value-added of Additional ² Coal Output (10 ⁶ 1972\$)	0	0.191	3.779	17.598	38.614	63.026	91.493	109.324	119.938

¹ Assuming an F.O.B price of coal of \$3.66/ton in 1972 dollars.

² Value-added = 58% of gross output.

(iii) Additional Severance Taxes (All Scenarios): These data are necessary to incorporate a major change in the calculation of severance taxes enacted by the State of Montana in 1975. NRIES' coefficients are estimated using time series data over the years 1956-1976 and thus do not reflect this change in its state revenue equation for Montana. Since the law affects all coal (not just new coal) produced in the state, the additional revenues for the state must be calculated on all coal expected to be produced in the forecast period.

Under the old tax law, tax revenues from the severance tax on coal (in current dollars) from 1977 to 1985 would be as calculated in the following tables. Taxes from the new law and the differences in revenues are also shown.

Additional Severance Taxes^{1,2}

Scenario IIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
(1) Total Output (10 ⁶ tons)	20.516	21.130	22.590	25.000	30.590	34.270	40.080	49.280	54.980
(2) Tax Revenues @ \$.34/ton (10 ⁶ current dollars) ³	6.975	7.184	7.681	8.500	10.401	11.652	14.987	16.755	18.693
(3) Tax Revenues (10 ⁶ 1972 dollars) ⁴	4.925	4.755	4.808	5.047	5.873	6.272	7.708	8.249	8.827
(4) Tax Revenues (10 ⁶ 1972 dollars) ⁵	4.925	5.073	5.424	6.002	7.345	8.228	10.583	11.832	13.200
(5) Gross Output (10 ⁶ 1972 dollars) ⁶	75.089	77.336	82.679	91.500	111.959	125.428	161.333	180.365	201.227
(6) New Severance Taxes @ 30% of gross output (10 ⁶ 1972 dollars)	22.527	23.201	24.804	27.450	33.588	37.628	48.400	54.111	60.368
(7) Additional Tax Revenues ⁴ [(6)-(3)] (10 ⁶ 1972 dollars)	17.602	18.446	19.996	22.403	27.715	31.356	40.692	45.862	51.541
(8) Additional Tax Revenues ⁵ [(6)-(4)] (10 ⁶ 1972 dollars)	17.602	18.128	19.380	21.448	26.243	29.400	37.817	42.279	47.168

Scenarios IIIa and IVb	1977	1978	1979	1980	1981	1982	1983	1984	1985
(1) Total Output	20.48	20.57	22.260	28.770	38.670	50.170	63.580	71.980	76.980
(2) Tax Revenues @ \$.34/ton (10 ⁶ current dollars)	6.963	6.994	7.568	9.782	13.148	17.058	21.617	24.473	26.173
(3) Tax Revenues (10 ⁶ 1972\$) ⁴	4.917	4.629	4.737	5.808	7.424	9.182	11.118	12.049	12.359
(4) Tax Revenues (10 ⁶ 1972\$) ⁵	4.917	4.939	5.345	6.908	9.285	12.046	15.265	17.282	18.483
(5) Gross Output (10 ⁶ 1972\$) ⁶	74.957	75.286	81.472	105.298	141.532	183.662	232.703	263.447	281.747
(6) New Severance Taxes @ 30% of gross output (10 ⁶ 1972\$)	22.487	22.586	24.441	31.589	42.460	55.087	69.811	79.034	84.524
(7) Additional Tax Revenues ⁴ [(6)-(3)] (10 ⁶ 1972\$)	17.570	17.957	19.704	25.781	35.036	45.905	58.693	66.985	72.165
(8) Additional Tax Revenues ⁵ [(6)-(4)] (10 ⁶ 1972\$)	17.570	17.647	19.096	24.681	33.175	43.041	54.546	61.752	66.041

¹The tax law changed severance taxes on exported coal from a per ton charge based upon the BTU content of coal per pound (7000 BTU/lb. or less: 12 cents/ton; 7001-8000 BTU/lb.: 22 cents/ton; 8001-9000 BTU/lb.: 34 cents; 9000 BTU/lb. or more: 40 cents/ton) to a charge based upon the dollar value of output (7000 BTU/lb. or less: 12 cents/ton or 20% of value, whichever is greater; 7001 BTU/lb. or over: 30% of the value of coal produced). This tax law has been challenged in the courts by Montana coal companies and the outcome expected from this litigation is unclear. We assume in this study that the new tax law will be upheld.

²We cannot account for additional severance tax revenues for 1975 and 1976 since NRIES forecasts from 1978 and lag relationships in the model only permit adjustment from 1977.

³Assuming an average BTU content of 8750 BTU/lb. of coal produced (tax rate of \$.34 per ton).

⁴Calculated using a moving BEA GNP deflator extrapolated from data for 1972-1977:

1972 = 100	1979 = 159.76*
1973 = 105.8	1980 = 168.43*
1974 = 116.02	1981 = 177.10*
1975 = 127.18	1982 = 185.77*
1976 = 133.88	1983 = 194.44*
1977 = 141.61	1984 = 203.11*
1978 = 151.09*	1985 = 211.78*

*estimated

⁵Calculated using 1977 BEA GNP deflator for all forecast years (1977 = 141.61; 1972 = 100).

⁶Assuming F.O.B. price of \$3.66/ton in 1972 dollars.

(iv) Capital Inputs from the Rest of the U.S. (All Scenarios):
Materials inputs for the construction (but not the operation) of energy facilities are assumed to be imported by Montana from the rest of the U.S. NRIES therefore requires data for the increase in value-added brought on by additional coal mining construction in this scenario. Materials input requirements for the construction of coal mines are given in Table 4-4. Value added can be calculated from total yearly material inputs from construction over the forecast period.

Material Requirements by Facility and Year
(millions of 1972\$)¹

Scenario IIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (4) ²	1.504 ³	6.012	6.012	5.516	0.201				
M-2 (2)		0.248	0.752	3.006	3.006	2.758	0.250		
M-3 (10)		1.240	3.760	15.030	15.030	13.790	1.250		
M-4 (12)				1.488	4.512	18.036	18.036	16.548	1.500
M-5 (10)					1.240	3.760	15.030	15.030	13.790
Total Materials Requirements By Year	1.504	7.500	10.524	25.040	23.989	38.344	34.566	31.578	15.290
Value-added of total materials requirements ⁴	.648	3.233	4.536	10.792	10.339	16.526	14.898	13.610	6.590

Scenario IIIa	1977	1978	1979	1980	1981	1982	1983	1984	1985
M-1 (10) ²	1.24	3.76	15.03	15.03	13.79	1.25			
M-2 (10)		1.24	3.76	15.03	15.03	13.79	1.25		
M-3 (10)		1.24	3.76	15.03	15.03	13.79	1.25		
M-4 (10)			1.24	3.76	15.03	15.03	13.79	1.25	
M-5 (10)				1.24	3.76	15.03	15.03	13.79	1.25
M-6 (10)					1.24	3.76	15.03	15.03	13.79
Total Materials Requirements by Year	1.24	6.24	23.79	50.09	63.88	62.65	46.35	30.07	15.04
Value-Added of Total Materials Requirements ³	.534	2.689	10.253	21.589	27.532	27.002	19.977	12.960	6.482

Scenario IVb	1977	1978	1979	1980	1981	1982	1983	1984	1985
Total Mining ⁵	1.24	6.24	23.79	50.09	63.88	62.65	46.35	30.07	15.04
U-1 (2600) ²	8.89	26.65	70.98	141.96	70.98	35.48			
U-2 (2600)			8.89	26.65	70.98	141.96	70.98	35.48	
G-1 (250)					47.74	144.17	190.87	95.43	
Total Materials Requirements by Year	10.13	32.89	103.66	218.70	253.58	384.26	308.20	160.98	15.04
Value-Added of Total Materials Requirements ⁴	4.366	14.176	44.677	94.260	109.293	165.616	132.834	69.382	6.482

¹ Using construction schedule in Table 4-2 and cost data in Tables 4-3, 4-4 and 4-5.

² Numbers in parentheses are annual production capacities.

³ Assuming mine M-1 is in second year of construction (first year ignored).

⁴ Assuming value added as a proportion of total materials requirements of .43 (derived from U.S. Department of Commerce, Annual Survey of Manufacturers 1976, U.S. GPO, June, 1978).

⁵ As calculated for Scenario IIIa.

(v) Transportation, Communications and Public Utilities
Value-Added (Scenario IVb):

Electric Generation by Facility and Year

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Additional Electricity Generated ¹ (in 10 ⁶ MWH)									
U-1	0	0	0	0	0	0	13.67	13.67	13.67
U-2	0	0	0	0	0	0	0	0	13.67
TOTAL	0	0	0	0	0	0	13.67	13.67	27.33
Value of Additional Electricity Generated (10 ⁶ 1972\$) ²	0	0	0	0	0	0	65.235	65.235	130.470
Value-Added of Additional Electricity Generated (10 ⁶ 1972\$) ³	0	0	0	0	0	0	24.789	24.789	49.579

¹ Assuming capacity factors of 0.6.

² Assuming price of electricity of .00477 1972\$/kwh which is an average wholesale price of electricity as supplied by the State of Montana Public Service Commission for 1977 deflated by the BEA GNP deflator for 1977.

³ Assuming value-added to total output ratio of .38 (adopted from T.H. Lee, Manager Strategic Planning Operation for G.E. Power Generation Group, Testimony before Connecticut Public Utilities Commission, 1/22/76, and Bechtel (1978)). Note: this figure should be interpreted with caution as it is based upon sparse data.

(vi) Manufacturing Value-Added (Scenario IVb): Coal Gasification
output is classified with the manufacturing sector for this analysis.

High BTU Gas Production by Year

	1977	1978	1979	1980	1981	1982	1983	1984	1985
Gas Output (10 ⁹ cu. ft) ¹	0	0	0	0	0	0	0	0	73.0
Value of Additional Gas Output (10 ⁶ 1972\$) ²	0	0	0	0	0	0	0	0	40.16
Value-Added of Additional Gas Output (10 ⁶ 1972\$) ³	0	0	0	0	0	0	0	0	13.61

¹ Assuming a capacity factor of .8.

² Assuming price of gas to equal the national average price of gas (per thousand cubic feet) for 1977, expressed in 1972 dollars using the BEA GNP deflator. (Price of gas taken from Energy Information Administration, U.S. DOE, Annual Report to Congress, Volume III, 1977, U.S. GPO, May, 1978.

³ Assuming value-added to gross output ratio of .331, adapted from 1976 value-added to value shipments ratio for SIC 299 for lack of any better information (U.S. Department of Commerce, Annual Survey of Manufacturers 1976, U.S. GPO, June, 1978). Note: These figures should be applied with extreme caution.

4.2.3 Direct Impacts

Direct impacts by sector and year associated with the three hypothesized scenarios for coal and coal-related development in the state of Montana are summarized in Table 4-6. The major assumptions that were used in deriving these data are:

- o all outputs are expressed in 1972 dollars
- o all direct manufacturing capital goods for construction of energy facilities supplied by out-of-state sources
- o outputs of coal mines, power plants, and gasification plants expressed in terms of value-added
- o price of coal based on F.O.B. price as reported for Montana by the Bureau of Mines
- o coal gasification output classified within the manufacturing sector. Value determined by national average price of gas (per thousand cubic feet) for 1977 (expressed in 1972 dollars)
- o value of electric output based on wholesale price of electricity for 1977 (expressed in 1972 dollars) as supplied by State of Montana Public Service Commission.

These impact estimates may be incorporated into NRIES through adjustments to constant terms in sector output equations for Montana beginning in 1977 through 1985. Although the analysis of regional and multiregional impacts was not undertaken as part of this research effort, an analysis of indirect impacts associated with Scenario IIIa has been completed by BEA and is presented in Wendling and Ballard (1979).

4.3 The DRI Macroeconomic Scenario

The DRI macroeconomic model is used throughout EIA for national economic forecasting and impact assessment purposes. Utilization of NRIES for similar research at the regional level within EIA would thus be enhanced if the basic assumptions underlying the two models, as expressed in the values set for their corresponding exogenous variables, were made as compatible as possible. Furthermore, the comparison of national economic output as forecasted by NRIES and DRI using equivalent exogenous variable values may be instructive in its own right.

Table 4-6

Summary of Annual Direct Impacts for Each Scenario by Sector¹
(in millions of 1972 dollars)

Direct Impacts Expressed In Terms Of Value Added Increases Over The Base Case

Scenario	Sector \ Year	1977	1978	1979	1980	1981	1982	1983	1984	1985
I	All Sectors	0	0	0	0	0	0	0	0	0
IIa	Construction	.65	3.26	4.56	10.85	10.54	16.59	14.98	13.66	6.62
	Mining	.08	1.38	4.48	9.59	21.46	29.27	50.10	61.14	73.24
	All Other Sectors	0	0	0	0	0	0	0	0	0
	Taxes ^{2,3}	17.60	13.45	20.00	22.40	27.72	31.36	40.69	45.86	51.54
	Capital Inputs From Rest of U.S.	.65	3.23	4.54	10.79	10.34	16.53	14.90	13.61	6.59
IIIa	Construction	.55	2.73	10.32	21.71	27.67	27.12	20.08	13.02	6.51
	Mining	0	.19	3.78	17.60	38.61	63.03	91.49	109.32	119.94
	All Other Sectors	0	0	0	0	0	0	0	0	0
	Taxes ^{3,4}	17.57	17.96	19.70	25.78	35.04	45.91	58.69	66.99	72.17
	Capital Inputs From Rest of U.S.	0.53	2.69	10.25	21.59	27.53	27.00	19.98	12.96	6.48
IVb	Construction	6.57	20.78	64.47	136.02	125.94	223.34	151.08	91.01	6.51
	Mining	0	.19	3.78	17.60	38.61	63.03	91.49	109.32	119.94
	Electric Utilities	0	0	0	0	0	0	24.79	24.79	49.58
	Manufacturing ⁵	0	0	0	0	0	0	0	0	13.61
	Taxes ^{2,4}	17.57	17.96	19.70	25.78	35.04	45.91	58.69	66.99	72.17
	Capital Inputs From Rest of U.S.	4.37	14.18	44.68	94.26	109.29	165.62	132.83	69.38	6.48

¹ Calculation of impacts is detailed in Appendix.

² "Taxes" are not a direct impact of mining production, but rather a change in the severance tax formula for coal exports enacted in 1975, which is not reflected in NRIES' coefficients. Tax impacts are allocated to the equation for GSRM - State Government, Charges and Miscellaneous Revenues.

³ Taxes calculated using a moving deflator which is a trend-line extrapolation of the BEA GNP deflator from 1972 (=100) to 1977. (GNP indices are given in the Appendix.) Direct impacts of taxation change calculated using a constant (1977) GNP deflator for all forecasting years (1977-1985) are (in millions of 1972 dollars): 17.50 (=1977), 18.13, 19.38, 21.45, 26.25, 29.40, 37.81, 42.27, 47.17 (=1985).

⁴ Taxes calculated using a moving deflator, as above. Direct impacts of taxation change using a constant (1977) GNP deflator for all forecasting years (1977-1985) are (in millions of 1972 dollars): 17.58 (=1977), 17.65, 19.09, 24.59, 32.91, 42.78, 54.37, 61.57, 65.95 (=1985).

⁵ Coal Gasification.

Since NRIES is a bottom-up econometric model, few macroeconomic variables are exogenously specified that essentially drive state-level forecasts. As shown in Table 4-7, there exist only 15 exogenous variables in NRIES for which there are corresponding variables in DRI macroeconomic forecasts.

Direct impacts associated with the DRI forecast are incorporated into NRIES by substituting one vector of exogenous variables for another. BEA forecasts of the 15 national variables in Table 4-7 are essentially replaced by those from a DRI forecast. However, to effect this substitution, the DRI forecast must first be normalized to the 1977 base year in NRIES. To normalize, the formula shown below is used.

$$B = \frac{X_o^{NRIES}}{X_o^{DRI}}$$

where B = normalizing factor

X_o^{NRIES} = NRIES data value for 1977

X_o^{DRI} = DRI data value for 1977

The next step is to compute the trend in the ratio of DRI to NRIES forecast values. This is done using the formula shown below:

$$T_t = B * \frac{X_t^{DRI}}{X_t^{NRIES}} * 100$$

where T_t = trend factor ratio of DRI to NRIES forecast in forecast period

X_t^{DRI} = DRI data value in forecast period t

X_t^{NRIES} = NRIES data value in forecast period t

The trend factor is constructed as a simple multiplicative index of the ratios between DRI and NRIES forecasts. As can be easily demonstrated, the trend value for 1977 will always be 100. A trend value of above (below) 100 indicates a higher (lower) value for the DRI variable.

Table 4-7

NRIES Exogenous Variables and Corresponding DRI Variables

Exogenous Variables	Labels	
	NRIES	DRI
Employment, Armed Forces	EGAF	EDOML
Net Exports of Goods and Services	PFTD	EX@M
Output, Armed Forces	XGAF	GFML72
Consumer Confidence Index	CCI	JATTC
Output, Mining	XMIN	JDIMDMI
Consumer Price Index, Gasoline	DCG	PCNGAS
Money Rate, Prime Commercial Paper, 4 to 6 months	FPCP	RMCMML4@6NS
Wholesale Price Index	DW	WPI
Output Deflator, Mining	DQMI	WPISØP1ØØØ
Output Deflator, Agriculture and Other	DQAF	WPIØ1
Wholesale Price Index, Coal	DWCO	WPIØ5
Federal Government Expenditures, Durable Goods	GEFD	GFO72
Federal Government Expenditures, Nondurable Goods	GEFN	GFO72
Federal GIA to State Governments	GSRF	VAIDGF@SL
Federal GIA to Local Governments	GLRF	VAIDGF@SL

Note: GIA = grants-in-aid.

To obtain the transformed NRIES value that will be used in the simulation, we multiply the trend factor times the present NRIES forecast data value.

$$X_t^{NRIES*} = T_t * X_t^{NRIES} * .01$$

or alternately

$$X_t^{NRIES*} = \frac{X_0^{NRIES}}{\frac{X_0^{DRI}}{X_t^{DRI}}} * \frac{X_t^{DRI}}{X_t^{NRIES}} * X_t^{NRIES}$$

where

$$X_t^{NRIES*} = \text{NRIES data value derived from DRI forecast, in period } t.$$

4.3.1 Direct Impacts

Direct impacts associated with the DRI Macroeconomic scenario are shown in Table 4-8 (expressed as the change in NRIES input). This table also defines NRIES and equivalent DRI variable names, NRIES (BEA) and DRI forecasts of these variables through 1985, normalization factors and calculated input values for exogenous national variables as forecast by DRI. The magnitudes of direct impacts identify major differences in the two macroeconomic forecasts from which can be estimated their likely effects on NRIES projections.

The DRI forecast used in this study tends to show a higher rate of inflation and interest rates than the BEA forecast in NRIES. Since NRIES for the most part models real flows, the rate of inflation will mainly affect the ratio between real and nominal values. Also, since wages are tied differently to the rate of inflation and nonwage income, the ratio of wage to nonwage income should change. Interest rates in NRIES primarily affect the construction industry (negatively) so there should be a slight decrease in economic activity due to this.

DRI, however, shows a strong foreign trade surplus starting in 1979 and remaining throughout the entire period. The surplus

Table 4-8

New NRIES Exogenous Variable Values Calculated from DRI Data

	1977	1978	1979	1980	1981	1982	1983	1984	1985
<u>Employment, Armed Forces</u>									
NRIES: 12 EGAF									
DRI: EDODML									
NRIES Forecast	1545.000	1580.000	1600.000	1630.000	1655.000	1660.000	1665.000	1670.000	1675.000
DRI Forecast	2.073	2.064	2.064	2.064	2.064	2.064	2.064	2.064	2.064
Normalized DRI/NRIES Ratio	(1977=100)	97.400	96.100	94.400	92.900	92.700	92.400	92.100	91.800
New NRIES Input		1538.292	1538.292	1538.292	1538.292	1538.292	1538.292	1538.292	1538.292
Change in NRIES Input		-41.708	-61.708	-91.708	-116.708	-121.708	-126.708	-131.708	-136.708
<u>Net Exports of Goods and Services</u>									
NRIES: 138 PFTD									
DRI: EXDM/GNP									
NRIES Forecast	.600	.600	.100	-.200	-.100	.100	.300	.000	-.100
DRI Forecast	.600	.600	-.060	-.140	-.240	-.430	-.600	-.610	-.560
Normalized DRI/NRIES Ratio	(1977=100)	100.000	-60.000	70.000	240.000	-430.000	-200.000	.000	560.000
New NRIES Input		.600	-.060	-.140	-.240	-.430	-.600	-.610	-.560
Change in NRIES Input		.000	-.160	.060	-.140	-.530	-.900	-.610	-.460
<u>Output, Armed Forces</u>									
NRIES: 65 XGAF									
DRI: GFML72									
NRIES Forecast	17762.000	18700.000	19000.000	19400.000	19900.000	20400.000	20900.000	21400.000	21900.000
DRI Forecast	65.800	66.200	66.900	68.500	70.400	72.400	73.700	75.200	76.800
Normalized DRI/NRIES Ratio	(1977=100)	95.600	95.000	95.300	95.500	95.800	95.200	94.900	94.700
New NRIES Input		17869.975	18058.933	18490.835	19003.720	19543.598	19894.519	20299.428	20731.331
Change in NRIES Input		-830.025	-941.067	-909.165	-896.280	-856.402	-1005.481	-1100.572	-1168.669
<u>Consumer Confidence Index</u>									
NRIES: 1 CCI									
DRI: JATTC									
NRIES Forecast	89.200	92.600	87.000	93.000	95.000	98.000	99.000	100.000	100.000
DRI Forecast	.868	.829	.823	.846	.833	.839	.863	.877	.873
Normalized DRI/NRIES Ratio	(1977=100)	92.000	97.200	93.500	90.100	88.000	89.600	90.100	89.700
New NRIES Input		85.192	84.576	86.939	85.603	86.220	88.686	90.125	89.714
Change in NRIES Input		-7.408	-2.424	-6.061	-9.397	-11.780	-10.314	-9.875	-10.28

Table 4-8 (continued)

	1977	1978	1979	1980	1981	1982	1983	1984	1985
<u>Output, Mining</u>									
NRIES: 56 XMIN									
DRI: JQINDMI									
NRIES Forecast	19904.000	19800.000	20400.000	22000.000	23000.000	24000.000	25000.000	25900.000	26700.000
DRI Forecast	1.180	1.236	1.271	1.313	1.345	1.366	1.402	1.439	1.472
Normalized DRI/NRIES Ratio	(1977=100)	105.300	105.100	100.700	98.600	96.000	94.600	93.700	93.000
New NRIES Input		20848.596	21438.969	22147.416	22697.186	23041.409	23648.650	24272.759	24829.396
Change in NRIES Input		1048.596	1038.969	147.416	-312.814	-958.591	-1351.350	-1627.241	-1870.604
<u>Consumer Price Index, Gasoline</u>									
NRIES: 18 DCG									
DRI: PCNGAS									
NRIES Forecast	1.882	2.055	2.185	2.296	2.420	2.536	2.664	2.785	2.917
DRI Forecast	1.738	1.848	2.017	2.200	2.401	2.620	2.859	3.119	3.395
Normalized DRI/NRIES Ratio	(1977=100)	97.400	100.000	103.800	107.400	111.900	116.200	121.300	126.000
New NRIES Input		2.001	2.184	2.382	2.600	2.837	3.096	3.377	3.676
Change in NRIES Input		-.054	-.001	.086	.180	.301	.432	.592	.759
<u>Money Rate, Prime Commercial Paper (4-6 mo.)</u>									
NRIES: 85 FPCP									
DRI: RMCML406NS									
NRIES Forecast	5.600	7.400	7.000	6.500	6.000	6.000	6.000	6.000	6.000
DRI Forecast	5.610	7.190	7.210	7.520	8.070	7.320	6.440	6.310	6.360
Normalized DRI/NRIES Ratio	(1977=100)	97.000	102.800	115.500	134.300	121.800	107.100	105.000	105.800
New NRIES Input		7.177	7.197	7.507	8.056	7.307	6.429	6.299	6.349
Change in NRIES Input		-.223	.197	1.007	2.056	1.307	.429	.299	.349
<u>Wholesale Price Index</u>									
NRIES: 40 DW									
DRI: WPI									
NRIES Forecast	1.942	2.100	2.210	2.300	2.400	2.490	2.590	2.680	2.780
DRI Forecast	1.942	2.093	2.229	2.368	2.516	2.667	2.832	3.010	3.192
Normalized DRI/NRIES Ratio	(1977=100)	99.700	100.900	103.000	104.800	107.100	109.300	112.300	114.800
New NRIES Input		2.093	2.229	2.368	2.516	2.667	2.832	3.010	3.192
Change in NRIES Input		-.007	.019	.068	.116	.177	.242	.330	.412

Table 4-8 (continued)

	1977	1978	1979	1980	1981	1982	1983	1984	1985
<u>Output Deflator, Mining</u>									
NRIES: 28 DQMI									
DRI: WPISOP1000									
NRIES Forecast	2.497	2.700	2.890	3.060	3.220	3.410	3.600	3.780	3.970
DRI Forecast	2.143	2.387	2.547	2.680	2.825	2.979	3.146	3.331	3.525
Normalized DRI/NRIES Ratio	(1977=100)	103.000	102.700	102.000	102.200	101.800	101.800	102.700	103.500
New NRIES Input		2.781	2.968	3.123	3.292	3.471	3.666	3.881	4.107
Change in NRIES Input		.081	.078	.063	.072	.061	.066	.101	.137
<u>Output Deflator, Agricultural and Other</u>									
NRIES: 27 DQAF									
DRI: WPI01									
NRIES Forecast	1.470	1.610	1.690	1.680	1.780	1.890	1.900	1.930	2.000
DRI Forecast	1.926	2.107	2.228	2.333	2.437	2.544	2.654	2.769	2.889
Normalized DRI/NRIES Ratio	(1977=100)	99.900	100.600	106.000	104.500	102.700	106.600	109.500	110.200
New NRIES Input		1.608	1.700	1.781	1.860	1.942	2.026	2.113	2.205
Change in NRIES Input		-.002	.010	.101	.080	.052	.126	.183	.205
<u>Wholesale Price Index, Coal</u>									
NRIES: 41 DMC0									
DRI: WPI05									
NRIES Forecast	389.400	430.000	462.000	491.000	523.100	554.300	588.700	622.000	658.800
DRI Forecast	3.021	3.268	3.614	3.997	4.421	4.889	5.406	5.980	6.583
Normalized DRI/NRIES Ratio	(1977=100)	98.000	100.800	104.900	108.900	113.700	118.400	123.900	128.800
New NRIES Input		421.238	465.836	515.204	569.857	630.181	696.821	770.808	848.534
Change in NRIES Input		-8.762	3.836	24.204	46.757	75.881	108.121	148.808	189.734
<u>Federal Government Expenditures, Durable Goods</u>									
NRIES: 97 GEFD									
DRI: GF072									
NRIES Forecast	11.400	11.800	12.300	12.900	13.500	13.000	12.500	12.000	12.500
DRI Forecast	19.950	21.931	21.291	22.973	23.094	24.641	24.884	24.971	25.930
Normalized DRI/NRIES Ratio	(1977=100)	106.200	98.900	101.800	97.800	108.300	113.800	118.900	118.500
New NRIES Input		12.532	12.166	13.127	13.196	14.081	14.219	14.269	14.817
Change in NRIES Input		.732	-.134	.227	-.304	1.081	1.719	2.269	2.317

Table 4-8 (continued)

<u>Federal Government Expenditures, Durable Goods</u>	1977	1978	1979	1980	1981	1982	1983	1984	1985
NRIES: 98 GEPN DRI: GF072									
NRIES Forecast	9.000	8.000	10.000	9.000	10.000	9.000	9.000	9.000	9.000
DRI Forecast	15.730	14.869	17.309	16.027	17.106	17.059	17.916	18.729	18.670
Normalized DRI/NRIES Ratio (1977=100)		106.200	98.900	101.800	97.8000	108.300	113.800	118.900	118.500
New NRIES Input		8.496	9.891	9.159	9.775	9.748	10.238	10.702	10.668
Change in NRIES Input		.496	-.109	.159	-.225	.748	1.238	1.702	1.668
<u>Federal GIA to State Governments</u>									
NRIES: 95 GERF DRI: VAIDGF0SL									
NRIES Forecast	45938.000	53000.000	56000.000	59000.000	58500.000	63000.000	68500.000	74500.000	80000.000
DRI Forecast	50.107	57.279	61.548	66.806	73.953	80.500	98.272	95.446	103.219
Normalized DRI/NRIES Ratio (1977=100)		99.100	100.800	104.000	115.900	117.100	118.100	117.500	118.300
New NRIES Input		52513.420	56426.768	61339.829	67799.953	73802.397	80928.163	87505.039	94630.813
Change in NRIES Input		-486.580	426.768	2339.829	9299.953	10802.397	12428.163	13005.039	14630.813
<u>Federal GIA to Local Governments</u>									
NRIES: 96 GLRF DRI: VAIDGF0SL									
NRIES Forecast	15946.000	17600.000	18700.000	20100.000	21000.000	23400.000	24000.000	25800.000	27500.000
DRI Forecast	17.393	19.021	20.552	22.794	26.547	29.900	30.928	33.054	35.481
Normalized DRI/NRIES Ratio (1977=100)		99.100	100.800	104.000	115.900	117.100	118.100	117.500	118.300
New NRIES Input		17438.419	18842.510	20897.129	24338.445	27412.319	28354.393	30303.759	32529.343
Change in NRIES Input		-161.581	142.510	797.129	3338.445	4012.319	4354.393	4503.759	5029.343

will tend to lower inflation rates and thus counterbalance some of the increase in the inflation rate.

The consumer confidence index, mainly affecting the consumption of nondurable goods in NRIES (implicitly through the savings rate), is lower in the DRI forecast as are growth rates in the armed forces employment and output and the output in mining. These factors can be expected to decrease the growth rate in forecasted economic activity in NRIES. On the other hand, government fiscal variables and grants-in-aid to State and local governments are consistently higher in the DRI forecast. This is likely to raise the level of the forecasted economic activity in the model. Net impacts to NRIES projections attributable to direct impacts from the DRI forecast, and the degree of correspondence between national variables in the two models can be estimated by simulating NRIES to 1985 with DRI-projected national exogenous variables.

4.4 AAR National Energy Scenario

The Midterm Energy Forecasting System (MEFS) is the primary forecasting framework in EIA for developing comprehensive projections of energy supply and demand in the U.S. based upon explicit scenario assumptions. The AAR National Energy scenario concerns itself with the transformation of energy supply, conversion and distribution projections associated with one of these forecasts into state-level direct economic impacts which can be input to NRIES. Rather than developing the data, however, this section suggests a methodology for transforming energy supply data from MEFS to input data for NRIES to enable the regional economic impacts of alternative energy supply-demand scenarios to be estimated.

The linkages between MEFS and NRIES are necessarily indirect because of sectoral, spatial and functional differences, and in order to place the methodology in context, the section first briefly describes how regional impacts are currently calculated from MEFS forecasts. It then outlines a framework for incorporating energy supply forecasts into NRIES and details data sources and other information which are required for translating MEFS outputs to the appropriate regional detail and quantities for input to NRIES.

Finally, the methodology and alternative approaches for developing the direct impacts associated with MEFS forecasts for NRIES are described and explained.

4.4.1 Current Regional Impacts Estimation Procedure

At present the Regional Socioeconomic Environmental Analysis Division at EIA uses a top-down approach for estimating the regional economic impacts associated with MEFS forecasts (Figure 4-1). The Regional Earnings Impact System (REIS) uses shift-share analysis (see Richardson, 1969, p. 344-345) to scale sectoral estimates of national economic activity to the state level.

This is accomplished by first developing a macroeconomic forecast from MEFS outputs. Variables taken from MEFS are:

- o prices for the eight energy products (crude petroleum, residual oil, distillate oil, gasoline, other refined products, natural gas, coal and electricity)
- o imports of crude oil and refined petroleum products
- o price of imported crude oil and refined petroleum products
- o gasoline consumption
- o retail gasoline price.

Since MEFS forecasts for the years 1985, 1990 and 1995 only, intermediate year inputs for these variables are interpolated back to the base year using historical data. A DRI macroeconomic model is presently used to produce the macroeconomic forecast for subsequent analysis.

Components of final demand for a given year from the macroeconomic model are input to a national input-output model to generate sectoral employment estimates in the next step of REIS. This involves first bridging 19 components of final demand into a 129-sector bill of goods for the input-output model (Sandoval et al., 1978, p.9). These components are:

Figure 4-1

Flow Chart of the Regional Earnings Impact System

- o personal consumption expenditures
 - autos and parts
 - furniture
 - other durables
 - food and beverage
 - clothing and shoes
 - gasoline and oil
 - other non-durables
 - housing
 - household operations
 - transportation
 - other services
- o investment
 - producer's durable equipment
 - structures
- o change in business inventories
- o exports
- o imports
- o defense and non-defense Federal expenditures
- o state and local government expenditures.

National employment projections from the input-output model are then aggregated to the 37 2-digit standard Industrial Classification (SIC) categories of OBERS which converts national employment to national earnings and regionalizes earnings in the 37 industrial sectors to the state level of detail. REIS uses an updated set of projected shares created by BEA for the Environmental Protection Agency which better reflects a post-embargo economy than do earlier OBERS forecasts. Further details of these recent projections are given in BEA (1977).

REIS forecasts are therefore in the form of state earnings projections by 37 industrial sectors. These data are scenario specific and may be used to compare the regional impacts of alternative MEFS forecasts against baseline projections or other forecasts. Examples of this may be seen in Sandoval et al. (1978).

The weaknesses of the REIS modeling system have been documented extensively in other papers (Sandoval et al., 1978; see also Chapter 3) and are not detailed here. In summary, these weaknesses relate to its failure to take into account the dynamics of regional change and to meaningfully address the interregional economic and demographic impacts caused by change in a given region. REIS also fails to account for economic indicators other than earnings, such as employment, tax revenues, transfer payments, sales and population which are of equal concern in the estimation of the regional impacts of alternative energy futures.

4.4.2 Estimating Regional Impacts of MEMS Forecasts With NRIES

To assess the potential for using NRIES to develop regional economic forecasts associated with MEFS outputs, an overall framework such as that shown in Figure 4-1 is required. Actually, the conceptual linkage between the energy and regional economic forecasts is quite simple (Figure 4-2) as the intention is to directly connect the two models without any intermediate modeling efforts. The linkage between models represents the vector of incremental capital and operating expenditures (over or under a baseline) required to attain the energy supply outputs forecast by MEFS. To effect this linkage, these marginal changes in energy supply must be transformed, by technology, to:

- o annual direct impacts
- o the state level of regional disaggregation
- o NRIES' sectoral level of detail (1-digit SIC) in value-added terms.

This implies that most direct impacts inferred from MEFS will affect state economic output equations in NRIES (particularly the construction and manufacturing sectors). However, other adjustments may be necessary as well (such as in various tax equations).

The energy supply technologies in MEFS that must be input to NRIES relate to energy production, conversion and transportation. In MEFS, production refers to the introduction of

Figure 4-2

Conceptual Linkage Between MEFS and NRIES

materials into the energy system through resource extraction or imports. The significant energy materials introduced at this stage are coal, oil and gas. The energy conversion process represents electric utilities, refineries, and synthetic fuel plants. Transportation activities move materials between regions via various modes.

The conversion of the MEFS "snapshot" forecast for 1985 to annual terms is a problem which has already been addressed in REIS, although a different set of variables are adjusted in this model than will be transformed for NRIES. Essentially, MEFS provides or can be used to provide cumulative constant dollar capital and operating expenditures over the forecast period. Historical values for these expenditures at the appropriate regional detail can then be used to interpolate annual expenditures between 1985 and the base year. If corresponding capital and operating expenditures by region cannot be obtained from historical data, proxy variables such as physical output (e.g., 10^6 tons of coal per year) can be used to establish intermediate year values.

MEFS supply forecasts must also be mapped to the state level of detail in order to provide inputs suitable for NRIES. Each of the model's energy production and conversion categories exists within its own regional definitions. Thus, there are 9 utility, 12 coal, 7 refinery, 3 shale, 13 oil and 14 gas regions defined in the supply model. The problem of developing state level inputs to NRIES is therefore two-fold:

- (i) for each production and conversion category, a region to state mapping must be developed so that states are correctly identified within their respective regions
- (ii) for each production and conversion category, a methodology must be developed which allocates regional energy activity to the state level.

The region-to-state mappings are relatively straightforward for some energy processes since regions are delineated along state

lines. Such is the case for utility and refinery regions (Figures 4-3 and 4-4). Region-to-state mappings for coal, oil and gas regions are problematic, however, since their boundaries cut through states; i.e., the integrity of state boundaries is not maintained (see Figures 4-5 and 4-6).

The allocation of regional energy supply, conversion and transportation totals in MEFS to state-level totals requires the development of appropriate sharing algorithms for allocating capital and operating expenditures by energy category and region to corresponding states. Although several sharing schemes can be suggested, OBERS state share projections for coal mining, crude petroleum and natural gas mining, petroleum refining, and transportation, communications and public utilities sectors appear most appropriate for developing region-to-state allocations. OBERS projections between 1975, 1985 and 1990 can be interpolated and renormalized to develop dynamic shares over the forecast period.

A final issue concerns the conversion of direct impacts associated with each energy supply, conversion and transportation technology in MEFS, expressed in terms of gross output or expenditures, to value-added terms and to appropriate sectoral definitions in NRIES. Output sectors in NRIES are defined to be:

- (1) agricultural, forestry, fisheries, other
- (2) mining
- (3) contract construction
- (4) manufacturing, durable goods
- (5) manufacturing, non-durable goods
- (6) transportation, communications, public utilities
- (7) wholesale and retail trade
- (8) finance, insurance and real estate
- (9) services
- (10) government, federal civilian
- (11) government, armed forces
- (12) government, state and local.

Given these definitions, the appropriate sectoral classification of MEFS outputs are shown in Table 4-9. Once sectoral assignments of MEFS outputs have been determined, they may be translated to value-added terms using value-added/gross output ratios derived from supplementary data (U.S. Department of Commerce, 1978) and input to NRIES.

Figure 4-3

Electric Utility and Demand Regions

Source: Federal Energy Administration, National Energy Outlook. Washington, DC: U.S. GPO, February (1976), p. A-2.

Figure 4-4

Refinery Regions

Source: Federal Energy Administration, National Energy Outlook.
Washington, DC: U.S. GPO, February (1976), p. A-3.

Figure 4-5

Coal Supply Regions

Figure 4-6
Oil and Gas Regions

Source: Federal Energy Administration, National Energy Outlook.
Washington, DC: U.S. GPO, February (1976), p. D-7.

Table 4-9

Mapping of MEFS Outputs to NRIES Sectors

NRIES Sector

Energy Category (MEFS)	Agriculture, etc.	Mining	Contract Construction	Manufacturing Durables	Manufacturing Non-Durables	Transportation, Comm., Utilities	Wholesale & Retail Trade	Finance, Ins., Real Estate	Services	Federal Government	Armed Forces	State and Local Government
Coal												
Development			X									
Operation		X										
Oil and Gas												
Development			X									
Operation		X										
Electric Utilities												
Development			X									
Operation						X						
Refineries												
Development			X									
Operation					X							
Synthetics												
Development			X									
Operation						X						
Transportation												
Development			X									
Operation						X						

4.4.3 MEFS-to-NRIES Direct Impact Conversion Algorithms

The previous section outlined a general methodology for converting MEFS energy supply forecasts into direct impacts compatible with NRIES and capable of being incorporated into its regional economic projections. This section attempts to operationalize this methodology by developing conversion algorithms for the energy supply and conversion technologies recognized by MEFS. In doing so it identifies data requirements and makes more explicit the assumptions employed to develop state-level impacts so that the methodology can be satisfactorily evaluated. Conversion algorithms for energy transportation impacts are not discussed in this section because of significant methodological problems, unique to this sector, which were not resolved in this study.

Figure 4-7 illustrates the methodology for converting resource production forecasts (coal, oil and gas) generated by MEFS to value-added direct impacts which can be input to NRIES. Output data from MEFS (to be used in the conversion) are annual regional production summaries, regional prices and cumulative capital investment requirements (between 1978 and 1985), by region and energy product, projected by the model conditional upon specified scenario assumptions (Step 1). For coal, regional production summaries are given in Table 17 of the MEFS Model Report,¹ a statistical summary of supply and demand forecasts associated with a given scenario; regional price summaries are given in Table 35; and capital requirements data are reported as inputs to the model and may be derived from the Appendix which accompanies the Annual Report to Congress (U.S. DOE, 1978a). Oil and gas production summaries for 1985 are given in Tables 5 and 6 in the MEFS Model Report. Regional wellhead prices for oil are given in Table 33 and gas wellhead prices in Table 34. Capital investment requirements can be extracted from input data developed to drive MEFS forecasts.

Once 1985 forecast values for resource production, prices and capital requirements are determined, production and price data are annualized back to the base year using historical and

¹The MEFS model report is a computer generated summary of energy projections associated with a given MEFS scenario for specified forecast years (1985, 1990, 1995). Examples of this report package in support of the 1978 Annual Report to Congress can be seen in U.S. DOE (1978a).

Figure 4-7

Conversion of MEFS Projections of Coal, Oil and Gas
Production to Direct Impacts for NRIES

Table 4-10

Variable Definitions in Figure 4-7

Q_{ijk}^{1985}	= production of energy resource type i, sub-type j in region k (MEMS)
P_{ijk}^{1985}	= F.O.B. price of energy resource type i, sub-type j in region k (MEMS)
ΣK_{ijk}^t	= $K(P_{ijk}^{1985})$ = cumulative capital requirements for producing Q_{ijk}^{1985} (MEMS)
Q_{ijk}^b	= base year production of energy resource i, sub-type j in region k (exogenous)
P_{ijk}^b	= base year price of energy resource i, sub-type j in region k (exogenous)
Q_{ijk}^t	= production of energy resource i, sub-type j in region k in year t (1978-1984) (interpolated)
P_{ijk}^t	= price of energy resource i, sub-type j in region k in year t (1978-1984) (interpolated)
$Q_{ijk}^{t'}$	= extrapolated production of energy resource i, sub-type j, region k in year t (1978-1984) from 1956-1976 data (exogenous)
ΔQ_{ijk}^t	= marginal production of energy resource i, sub-type j, region k in time t over extrapolated baseline (calculated)
ΔK_{ijk}^t	= marginal capital requirements over extrapolated baseline (calculated)
ΔX_{ijk}^t	= \$ output associated with the marginal production of energy resource i, type j, region k, in time t (calculated)
f_{iks}^t	= proportion of \$ output in energy sector i allocated to state s in region k (exogenous)
ΔX_{iks}^t	= \$ output associated with the marginal production of energy resource i, region k, state s in time t (calculated)
ΔK_{iks}^t	= marginal capital requirements in state s associated with ΔX_{iks}^t

base year data and other relevant information (Step 2). As an example of the latter, the MEFS Appendix contains price trajectories for alternative price steps which may be directly or indirectly applied to obtain annual F.O.B. price data for oil and natural gas. In the absence of any supplementary information, output and prices can be "straight-lined" back from 1985 forecast values to base year estimates. Although this introduces distortions into annual production and price estimates, it can be expected that the time interval between the base year and forecasting horizon is small enough to prevent errors from becoming significant.

The major problem foreseen in developing input data for NRIES relates to describing MEFS energy supply forecasts in terms of direct impacts. MEFS output estimates must therefore be expressed in terms of marginal deviations from a baseline projection (Step 3). Ideally, a baseline forecast from NRIES should be used to calculate marginal output and capital investment changes associated with projected values from MEFS. However, NRIES sector definitions are too aggregate to be used for this purpose and approximations to baseline forecasts for each energy product must be made. The approximation proposed in this design involves the calculation of deviations in annualized production levels from baseline forecasts estimated by extrapolating, from 1956 to 1976 data (the estimation period of NRIES), physical output levels of each resource. Although likely to distort marginal output estimates somewhat, this method offers perhaps the greatest precision for calculating direct impacts. Historical data for extrapolating trends are available from DOE and other government sources. Note that marginal capital requirements forecasts are not calculated by extrapolating capital investment trends but are instead based on marginal output estimates. This procedure is undertaken because of anticipated problems finding serial data on capital expenditures by energy product and region.

Annual capital requirements present further problems which require considerably simplified spatial and temporal estimates to be used as inputs to NRIES. These problems relate primarily to the lag relationships between output and capital investment and how data are presented in MEFS.

MEFS reports annual production levels of energy resources expected by 1985 under a set of specified assumptions. It also reports total capital investment requirements to meet this output level; that is, for each region and resource sub-type (coal is used as an example here), the data report the incremental and cumulative supply of the resource expected at each price step, thereby simulating a supply curve, plus the capital investment required to produce that increment in supply. However, the temporal distribution of investment is not considered.

Consider a scenario which forecasts a 1985 output level for a given resource, x , to be, say, x^{1985} , in response to an F.O.B. price of p^{1985} . Capital requirements associated with this output level are q^{1985} . For simplicity in this example, we may annualize production by assuming constant growth in output over the period Δ between the baseline and 1985. Therefore:

$$x^t = x^b + \left(\frac{x^{1985} - x^b}{\Delta} \right) t$$

x^t = output in year t
 x^b = output in the base year
 x^{1985} = output in 1985

If we impose a lag relationship such as the one for coal mining development in the Montana coal scenario, i.e.,

$$\begin{bmatrix} q^{t-5} \\ q^{t-4} \\ q^{t-3} \\ q^{t-2} \\ q^{t-1} \\ q^t \end{bmatrix} = f(x^t) \begin{bmatrix} .025 \\ .075 \\ .3 \\ .3 \\ .275 \\ .025 \end{bmatrix} \quad (4.4.1)$$

several problems arise. First, marginal capital requirements are backcast to time periods prior to the forecast interval of NRIES. Annual construction sector direct impacts cannot be changed in the years prior to 1977 in the model, nor should they be, since we would, in effect be altering history. Second, to adequately capture all construction sector impacts, output

forecasts to 1990 would have to be considered since, to achieve given output levels in the 1985-1990 time period, construction would have commenced prior to 1985. Third, lagged investment data shown above relate to individual mines, not aggregate output levels as given by MEFS. There is no information about the phasing of individual mines (in this case) in the model which makes the application of the lag distribution in (4.4.1) inappropriate.

Since we are dealing with aggregate regional output levels and since capital investment activities to meet 1990 production forecasts are occurring before 1985, thus making the specification of lag relationships in this context exceedingly arbitrary, the methodology here assumes that 1985 cumulative capital investment levels are averaged over the 1978-1985 forecast interval according to annual production estimates, in effect, concealing lags in output due to construction.¹ Marginal capital inputs for a given year, t , are thus related to output levels for that year. Therefore, under this scheme:

$$q_t = \frac{x^t}{\sum_{t=b}^{1985} x^t} \cdot q^*$$

where q^* = total capital requirements to meet production forecasts for 1985.

Marginal capital requirements are allocated in the same proportions to total capital requirements as are marginal output levels. This, of course, does not recognize changing real costs of resource capital nor changing investment decisions based on resource prices (which are recognized by MEFS).

¹Wendling and Ballard (1979) take an opposite approach in the AAR Coal scenario, incorporating lags into coal output forecasts.

Step 5 is designed to convert annual marginal output in physical units to annual dollar output terms. When factored by a value-added-to-gross output ratio and allocated to states, these data provide direct production impacts for NRIES. Prices for converting physical to dollar units are derived from Step 2.

The allocation of regional marginal output figures, by year, to state data is undertaken in Step 6. Input data are state shares of a given regional activity and are derived from OBERS projections. Marginal capital investment impacts by state and year are then generated in the same proportions as dollar outputs (Step 7). Inter-state differences in investment requirements are therefore explicitly excluded for lack of data.

Finally, capital and operating impacts by state and year are mapped to the appropriate economic sectors in NRIES and factored by corresponding value-added-to-gross output ratios to arrive at the direct impacts of the resource extraction forecast of MEFS suitable for input to NRIES.

Although conceptually similar to that of resource extraction, conversion algorithms for the electric utilities and petroleum refining sectors in NRIES have been modified to accommodate definitional conventions in the MEFS Model Report and characteristics of historical data available for developing baseline forecasts. The methodology for converting MEFS' electric utility construction and generation forecasts into direct impact input estimates for NRIES is shown in Figure 4-8. Output data taken from MEFS relate to the annual generation of electricity and average delivered price of electricity in 1985 by region, and the total capacity-added since the base year by generating technology and region. These data are presented in Tables 26 and 30 of the MEFS Model Report. Exogenous data required to disaggregate these estimates are:

- o historical time series data on installed generating capacity by technology and region
- o historical time series data on annual generation of electricity by region

Figure 4-8

Conversion of MEFS Electric Utility Projections
to Direct Impacts for NRIES

Table 4-11

Variable Definitions in Figure 4-8

Q_k^{1985}	= annual generation of electricity in region k year 1985
p_k^{1985}	= average delivered price of electricity in region k in 1985
p_k^b	= base year average delivered price of electricity in region k
Q_k^b	= base year annual generation of electricity in region k
EC_{ik}^t	= total capacity-added of technology i region k since the base year (1978)
Q_k^{xt}	= annual generation of electricity in region k year t extrapolated from historical data
ΔQ_k^t	= marginal annual generation of electricity in region k year t over the baseline
ΔX_k^t	= gross output of electric utilities sector region k year t
f_{ks}^t	= proportion of region k production in state s in year t
ΔX_{ks}^t	= gross output of electric utilities in region k/state s in year t
EC_{ik}^{xt}	= total capacity added of technology i in region k since the base year extrapolated from historical data
ΔEC_{ik}^t	= marginal capacity added of technology i in region k since the base year over the baseline
ΔC_{ik}^t	= marginal capacity added of technology i in region k since the base year over the baseline
UK_{ik}	= unit capital cost of technology i in region k
UK_{ik}^t	= unit capital cost of technology i region k year t
ΔK_{ik}^t	= capital cost of technology i region k year t
ΔK_{ks}^t	= capital cost in region k/state s year t

- o unit capital costs (\$/kW) of generating capacity by technology and region
- o state shares of electrical generating dollar output by utility region.

The major difference between the resource extraction and electric utility conversion algorithms concerns the manner in which construction sector (capital costs) impacts are estimated. Capital investment requirements in the former for satisfying projected production levels were taken directly from the MEFS input data base; in the latter, they are calculated from unit capital cost estimates which are also contained in the data base. Marginal capacity-added by technology and region is first calculated over an extrapolated baseline from which capacity additions for each year are derived. Capital investments by technology, region and year are then estimated by applying technology-specific unit capital cost data to marginal capacity-added. Marginal capital investment requirements are aggregated over all technologies and are finally shared to states in proportions derived from OBERS projections.

The methodology for converting MEFS petroleum refining forecasts into direct impact estimates for NRIES is shown in Figure 4-9. Output data taken from MEFS are per day physical production estimates and prices by refinery product and region for 1985. Refinery products considered by MEFS are:

- o gasoline
- o jet fuel
- o liquid petroleum gases
- o distillate oil
- o residual oil
- o still gas
- o naptha
- o other refined petroleum.

Daily production figures are given in Table 23, and product prices in Table 32, of the MEFS Model Report. Exogenous data required to transform MEFS production estimates to direct economic impacts are:

Figure 4-9
Conversion of MEFS Petroleum Refining
Projections to Direct Impacts for NRIES

Table 4-12

Variable Definitions in Figure 4-9

Q_{jk}^{1985}	= per day physical production of refinery product j, region k in 1985
P_{jk}^{1985}	= price of refinery product j, region k in 1985
Q_k^b	= per day physical production of all refinery products, region k in base year
P_{jk}^b	= price of refinery product j, region k in base year
Q_k^t	= per day physical production of all refinery products, region k in year t
C_k^t	= capacity of refineries in region k in year t
Q_k^{xt}	= extrapolated per day physical production of all refinery products, region k in year t
C_k^{xt}	= extrapolated capacity of all refineries in region k, year t
q_{jk}^{1985}	= proportion of refinery product j produced per unit of all refined products in region k
ΔQ_{jk}^t	= marginal per day physical production of refinery product j, region k in year t
UK	= unit capital cost (per 10^3 bbls output) of refineries
ΔX_k^t	= marginal annual output of refineries, region k in year t
f_{pks}^t	= proportion of region k production in state s in year t
ΔK_k^t	= marginal capital requirements for refining in region k year t
ΔK_{ks}^t	= marginal capital requirements for refining in state s, region k in year t

- o time series data on product prices by region
- o time series data of refinery output and capacity by region
- o unit capital costs of refinery construction
- o refinery products as proportions of total output
- o state shares of refinery region activity.

This conversion algorithm differs from the first two in the way it calculates capital investment. MEFS refinery forecasts are expressed solely in terms of physical output; no refinery capacity estimates are projected to 1985. Capacity figures are therefore calculated from total refinery output forecasts by applying a constant capacity factor; unit capital costs are then factored to refinery capacity estimates to determine marginal capital investment impacts embodied in MEFS forecasts. Total marginal dollar output estimates must also be converted to annual terms to be compatible with NRIES.

Although conversion algorithms for transforming MEFS outputs to NRIES inputs have been developed for only the energy supply and conversion activities in MEFS forecasts, data requirements and methodological assumptions implicit in this approach are apparent. Clearly, the number of data sources and amount of data required to estimate state-level impacts on economic output are significant.

Five basic types of data can be considered necessary to effect the required transformations. The first is the energy forecast, itself, which is comprised of outputs from a MEFS scenario. These are the raw data which must be converted to input data for NRIES. Second, region-to-state mappings for each energy supply, conversion and transportation activity are required to identify states impacted by regional forecasts. Third, state shares of economic activity (earnings) related to these energy activities are required to apportion direct impacts to identified states or fractions of states in defined regions. Fourth, base year (1978) data on output, price and capital investment or capacity are needed to annualize MEFS snapshot forecast estimates over the projection period. Finally, time series data concerning physical output for each energy supply, conversion and transportation technology are required to develop baselines from which marginal deviations in dollar output and capital expenditures associated with MEFS forecasts can be calculated.

While most of these data exist in EIA, and some are used as input to MEFS, many data sets require some transformation to make them compatible with MEFS base year assumptions and short-term forecasts. To develop direct impacts incorporating the least error, a concerted data gathering effort within EIA should be conducted.

However, regardless of the quality of data used to estimate direct impacts, the methodological assumptions embodied in this approach are subject to criticism. These assumptions are mainly a function of the "distance" between MEFS outputs and NRIES inputs. Two assumptions which are most tenuous relate to the development of state-level data from regional control totals and the calculation of marginal changes in capacity and production. With respect to the former, state-level data are derived from regional estimates via a top-down sharing mechanism (in this case OBERS projections of state earnings by individual sector). In addition to violating the bottom-up philosophy which characterizes NRIES, such an approach is subject to the same criticisms as explained in Chapter 3. OBERS shares essentially ignore interstate economic linkages between energy production, conversion and transportation sectors. Furthermore, these shares are based upon historical trends which are likely to shift in response to alternative energy trajectories hypothesized in MEFS. That the sharing mechanism cannot respond to alternative scenario forecasts implies that some degree of error is being introduced into state output estimates.

The second assumption is perhaps more fundamental to the methodology. In order to define MEFS projections in terms of direct impacts, forecasts of energy production activities must be expressed in terms of deviations from prescribed baselines. The employment of surrogate baseline forecasts, because sector definitions in NRIES are too aggregate, is intended to estimate the marginal changes in activity. However, since surrogate baselines are essentially independent from those embodied in NRIES baseline forecasts, there may be no correspondence whatsoever between direct impacts as calculated by the methodology and

those actually associated with the MEFS forecast and NRIES baseline. But no more precise method for determining impacts can be suggested without further sector disaggregation in NRIES, which is a development task not currently being considered by BEA.¹

Clearly, other consistency problems exist in the methodology. For example, there is no guarantee that national macroeconomic parameters derived from aggregating NRIES final demand estimates, which embody MEFS direct impacts, actually approximate those (from the DRI macroeconomic model) which drive MEFS projections. (This suggests the incorporation of a feedback loop between NRIES and the macroeconomic driver of MEFS in Figure 4-2.) However, compared to current regional economic forecasting capabilities (REIS) in EIA, the linkages between MEFS forecasts and NRIES are no less precise.

To illustrate the methodology, state-levels direct impacts to the contract construction and non-durables manufacturing sectors of NRIES from petroleum refining forecasts in the MEFS Series C Medium World Oil Price Scenario (2/12/79) have been estimated.² Petroleum refining was chosen for analysis because historical data on production and capacity on a regional basis were most accessible and Petroleum Administration for Defense (PAD) regions are easily mapped to the state level. Historical time-series data on refinery output and capacity were derived from Trends in Refinery Capacity and Utilization (U.S. DOE, 1978b). State shares of petroleum refining activity between 1977 and 1985 were developed from updated OBERS projections of state

¹An alternative methodology for constructing a baseline has been suggested by BEA. The methodology essentially assumes a baseline scenario from alternative MEFS forecasts. That MEFS scenario which is qualitatively assessed to most closely correspond to the NRIES baseline projection is designated as the MEFS baseline projection. Direct impacts associated with all other MEFS forecasts are then estimated by calculating differences in energy production and conversion activity from the designated baseline. These impact estimates are then transformed to appropriate units for input to NRIES.

²The reader should be cautioned that these estimates are preliminary and have not been validated nor have they been input to NRIES to assess associated indirect and induced impacts. Significant errors are likely embodied in these estimates.

earnings for petroleum refining and related products. Projected refinery output, expressed in terms of crude oil input per day for 1985, and product prices were developed from MEFS output.

Annual physical output levels from refineries by PAD region, estimated by interpolating 1985 estimates to the base year (1977), are shown in Table 4-13. A baseline refinery output forecast (crude oil input per day) by region was developed by extrapolating historical data covering the 1960 to 1977 time period. Direct refinery output impacts (Table 4-14) were obtained by subtracting baseline estimates from the annualized MEFS forecasts and were then converted to dollar output terms by applying region-specific refined product allocation fractions and product prices. These data were derived from the MEFS Model Report and the Appendix to the Annual Report to Congress (U.S. DOE, 1978a). Capital investment requirements in the MEFS forecast were obtained by assuming refinery capacity to be 10 percent greater than average crude oil input (an historical average). Cumulative capital requirements were then calculated by estimating marginal capacity required to produce at projected 1985 output levels (from existing 1977 capacity). The difference between cumulative capital requirements and a baseline estimate for each region was then computed, converted to dollars and apportioned in equal increments over the forecast period. These impacts are shown in Table 4-14.

Finally, regional direct impact estimates were converted to value-added and apportioned to states using shares developed from OBERS projections. Capital investment impacts were allocated to contract construction sectors and production impacts to non-durable manufacturing sectors in NRIES state equations. Estimated state-level impacts are shown in Table 4-15.

Although the methodology likely introduces considerable error into state-level impact estimates (e.g., non-zero impact estimates for Connecticut, Massachusetts and Iowa are distortions introduced by shares developed from OBERS projections), the example demonstrates that, with refinement, a procedure can be developed for converting MEFS energy forecasts into direct impact estimates suitable for input to

Table 4-13

Estimated Annual Refinery Output from MEFS
Series C Medium World Oil Price Scenario
 (Expressed as 10^3 bbl Crude Oil Input Per Day)

P.A.D. District	Crude Oil Input/Day by Year ¹ (10^3 bbl)								
	1977	1978	1979	1980	1981	1982	1983	1984	1985
1	1675	1733	1791	1849	1907	1964	2022	2080	2138
2	3779	4057	4335	4612	4890	5168	5446	5723	6001
3	6362	6445	6527	6610	6693	6775	6858	6940	7023
4	469	476	483	490	497	503	510	517	524
5	2323	2397	2471	2545	2619	2692	2766	2840	2914

¹Output in years between 1977 and 1985 interpolated from 1985 estimates.

Table 4-14

Estimated Annual Direct Impacts in Output and Capital Investment of MEFS
Refinery Production Forecast: Series C Medium World Oil Price Scenario
(Millions of 1972 Dollars)

P.A.D. District	Year								
	1977	1978	1979	1980	1981	1982	1983	1984	1985
Output									
1	0	65.6	136.9	213.7	296.2	384.2	477.9	574.9	679.7
2	0	427.7	887.0	1,375.5	1,898.0	2,452.0	3,035.1	3,652.2	4,301.1
3	0	-204.0	-422.0	-658.4	-911.2	-1,177.8	-1,463.0	-1,764.6	-2,079.8
4	0	-6.5	-15.7	-23.3	-33.7	-42.4	-53.9	-63.6	-76.4
5	0	19.9	41.6	62.9	87.9	112.4	140.6	170.6	199.9
Capital Investment									
1	0	131.1							→
2	0	468.8							→
3	0	-285.7							→
4	0	-25.3							→
5	0	-34.2							→

Table 4-15

State-level Direct Impacts Associated with MEFS
Refinery Output Forecast: Series C Medium World Oil Price Scenario
(Value-added in Millions of 1972 Dollars)

P.A.D. District	State	1978		1979		1980		1981		1982		1983		1984		1985	
		CC ¹	MAN ²	CC	MAN	CC	MAN	CC	MAN	CC	MAN	CC	MAN	CC	MAN	CC	MAN
1	CN	1.2	.6	1.2	1.3	1.3	2.1	1.3	3.0	1.4	4.1	1.5	5.4	1.5	6.8	1.6	8.4
	DE	1.1	.5	1.1	1.2	1.1	1.8	1.2	2.6	1.2	3.4	1.2	4.4	1.2	5.3	1.2	6.4
	FL	.7	3.7	.8	7.9	.8	1.3	.8	1.8	.8	2.4	.8	3.0	.8	3.7	.9	4.5
	GA	.8	.4	.8	.8	.8	1.3	.8	1.8	.8	2.4	.8	3.0	.8	3.6	.8	4.3
	MD	.7	.3	.7	.7	.7	1.1	.7	1.5	.7	1.9	.7	2.4	.7	2.9	.7	3.4
	MA	.8	.4	.8	.8	.8	1.3	.8	1.9	.8	2.4	.8	3.1	.8	3.7	.9	4.4
	NJ	9.0	4.5	9.1	9.6	9.3	15.1	9.4	21.1	9.5	27.7	9.6	34.8	9.7	42.3	9.7	50.6
	NY	10.7	5.3	10.7	11.1	10.6	17.3	10.6	24.0	10.6	31.0	10.6	38.5	10.5	46.1	10.5	54.3
	PA	12.8	6.4	12.6	13.1	12.3	20.1	12.1	27.3	11.9	34.8	11.6	42.4	11.4	50.0	11.2	58.0
	WV	.8	.4	.8	.8	.9	1.4	.9	2.0	.9	2.7	1.0	3.6	1.0	4.5	1.1	5.5
2	IL	48.4	44.2	48.9	92.6	49.4	144.9	49.8	201.8	50.3	262.9	50.7	328.0	51.0	397.6	51.4	471.5
	IN	13.3	12.1	12.8	24.2	12.3	36.0	11.8	47.6	11.3	59.1	10.9	70.3	10.4	81.3	10.1	92.3
	IA	.5	.4	.5	.9	.5	1.3	.5	1.8	.4	2.3	.4	2.8	.4	3.4	.4	4.0
	KS	7.5	6.8	7.3	13.7	7.0	20.7	6.8	27.7	6.6	34.7	6.4	41.7	6.2	48.7	6.1	55.6
	KY	8.0	7.3	8.5	16.0	8.9	26.2	9.4	38.0	9.9	51.7	10.4	67.4	10.9	85.3	11.5	105.6
	MI	7.8	7.1	7.8	14.8	7.8	22.9	7.8	31.7	7.8	40.9	7.8	50.6	7.8	60.9	7.8	71.6
	MN	4.0	3.6	3.9	7.5	3.9	11.5	3.9	15.7	3.9	20.2	3.8	24.8	3.8	29.5	3.8	34.5
	MO	2.6	2.4	2.5	4.8	2.5	7.2	2.4	9.7	2.3	12.2	2.3	14.6	2.2	17.1	2.1	19.5
	NB	.4	.4	.4	.8	.4	1.2	.4	1.6	.4	2.1	.4	2.7	.4	3.3	.4	3.9
	ND	1.2	1.1	1.2	2.3	1.2	3.6	1.3	5.1	1.3	6.8	1.3	8.7	1.4	10.7	1.4	12.9
	OH	25.2	23.0	25.2	47.6	25.1	73.6	25.0	101.1	24.8	130.0	24.7	160.0	24.5	191.2	24.4	223.4
	OK	18.7	17.0	18.6	35.2	18.5	54.3	18.4	74.6	18.3	95.9	18.2	118.1	18.1	141.3	18.0	165.3
	SD	.5	.4	.5	.9	.5	1.4	.5	2.1	.5	2.7	.5	3.5	.5	4.3	.6	5.1
	TN	1.8	1.6	1.8	3.4	1.8	5.3	1.8	7.4	1.9	9.8	1.9	12.3	1.9	15.0	1.9	17.9
	WI	.9	.8	.8	1.6	.8	2.5	.8	3.3	.8	4.3	.8	5.2	.8	6.2	.8	7.3
3	AL	-2.0	-1.4	-2.0	-3.0	-2.1	-4.8	-2.2	-6.9	-2.2	-9.2	-2.2	-11.7	-2.4	-14.5	-2.5	-18.0
	AR	-1.8	-1.3	-1.7	-2.5	-1.6	-3.8	-1.6	-5.0	-1.5	-6.3	-1.5	-7.5	-1.4	-8.7	-1.4	-10.0
	LA	-17.0	-12.2	-17.0	-25.1	-16.9	-39.0	-16.9	-53.8	-16.8	-69.3	-16.7	-85.7	-16.6	-102.5	-16.8	-122.3
	MS	-2.9	-2.1	-3.0	-4.5	-3.2	-7.3	-3.3	-10.5	-3.5	-14.3	-3.7	-18.8	-4.2	-26.2	-3.0	-21.9
	NM	-1.2	-.9	-1.2	-1.8	-1.3	-2.9	-1.3	-4.1	-1.3	-5.4	-1.3	-6.9	-1.4	-8.4	-1.4	-10.2
	TX	-60.8	-43.4	-60.7	-89.7	-60.6	-139.7	-60.5	-193.0	-60.3	-248.9	-60.2	-308.3	-59.8	-369.1	-60.6	-441.5
4	CO	-1.3	-.3	-1.3	-.8	-1.3	-1.2	-1.3	-1.7	-1.3	-2.2	-1.3	-2.8	-1.3	-3.3	-1.3	-3.9
	MT	-1.7	-.5	-1.7	-1.1	-1.7	-1.6	-1.7	-2.3	-1.7	-2.8	-1.7	-3.5	-1.6	-4.1	-1.6	-5.0
	UT	-1.2	-.3	-1.2	-.7	-1.2	-1.1	-1.1	-1.5	-1.1	-1.9	-1.1	-2.3	-1.1	-2.7	-1.0	-3.1
	WY	-3.3	-.8	-3.3	-2.1	-3.4	-3.1	-3.4	-4.6	-3.5	-5.8	-3.5	-7.5	-3.6	-9.0	-3.6	-11.0
5	CA	-9.0	5.3	-8.9	10.9	-8.8	16.3	-8.8	22.5	-8.7	28.6	-8.6	35.4	-8.5	42.5	-8.4	49.2
	HI	-.2	.1	-.2	.3	-.2	.4	-.2	.6	-.3	.8	-.3	1.1	-.3	1.4	-.3	1.8
	OR	-.2	.1	-.2	.3	-.2	.4	-.3	.6	-.3	.9	-.3	1.1	-.3	1.4	-.3	1.0
	WA	-.7	.4	-.8	1.0	-.8	1.5	-.9	2.3	-.9	3.1	-1.0	4.1	-1.0	5.2	-1.1	6.4

¹CC = Contract Construction

²MAN = Non-durables Manufacturing

NRIES. Provided that errors in the linkage between the two models are minimized, comprehensive regional assessments of alternative energy supply and demand strategies can thus be undertaken which more accurately estimate the magnitudes and spatial extents of their associated impacts than top-down regional models currently used.

4.5 Summary

This chapter has described methodologies for developing input data for NRIES which define the direct impacts associated with three scenarios chosen for analysis in this research effort. It has created data for state-level scenarios concerning alternative coal development strategies in the state of Montana based upon capital and operating cost estimates and expected construction schedules. The chapter has also normalized chosen macroeconomic parameters forecast by the DRI macroeconomic model to enable them to be input to NRIES in the form of direct impacts. Finally, the chapter has demonstrated, by example, how energy supply, conversion and transportation forecasts generated by MEFS can be transformed into direct impact estimates for NRIES.

That direct impacts from state, multi-state and national energy policy decisions can be formulated for NRIES indicates the feasibility of using the model in EIA to conduct regional economic impact assessments. However, several issues remain to be examined which must be considered before the suitability of NRIES for addressing the types of issues of interest to EIA can be firmly established. These are briefly discussed in the following chapter.

Evaluation of the NRIES/DREEM Framework

Although the context for evaluating the model has been somewhat limited by constraints on the scope of work in this research effort, scenario and data development tasks have provided a relevant perspective for assessing NRIES' potential for incorporation into a direct regional energy/economic modeling (DREEM) framework. Combined with an evaluation of the model based upon analysis of model output, this assessment can suggest directions for future research and applications relating to energy-economic interactions. The reader is referred to Ballard and Wendling (1978), Ballard, Glickman and Wendling (1979), Ballard, Glickman and Gustely (1979), and Wendling and Ballard (1979) for examples of analysis undertaken on NRIES simulations of energy and non-energy related scenarios.

Preliminary research into the structure and properties of NRIES has found the model to be appropriate for analyzing only a subset of energy policy decisions likely to be considered in EIA. Policies related to energy development, involving capital expansion and/or changes in energy production, have been suggested to be most appropriate; those related to energy pricing or allocation decisions, on the other hand, have been found generally to be infeasible since NRIES lacks the required parameters (such as prices) for dealing with these issues. Scenarios developed in this study have therefore concentrated upon hypothesized changes in industrial output in selected states attributable to energy policies or upon changes to fundamental national macroeconomic parameters in (NRIES representation of) the U.S. economy.

The linkages between hypothesized policies and NRIES, which essentially determine the direct impacts to be input to the model, have been found to be most direct and transparent in scenarios reflecting policies which concern specific facility development decisions or in those which relate to national economic activity. Linkages for the former are transparent because associated policies are specific enough to spatially define impacted areas and to

permit the generalization of facility-specific microdata, such as those for construction and operating schedules, capital costs estimates and other data which may be regionally identified. Linkages for the latter are transparent because a well-defined mapping of variables exists for adjusting the macroeconomic portion of NRIES and thus for translating national economic impacts into appropriate input data.

Linkages have been found to be least direct and transparent in the multistate scenario considered in this study, as it was found to require an extensive methodology for transforming projected output and production levels into direct impact estimates compatible with NRIES' regional and sectoral definitions. These linkages are likely to introduce considerable error into impact estimates. Data requirements for affecting transformations from policy statements to direct impacts are also most demanding in the multi-state scenario. This is attributable both to the comprehensiveness of energy production forecasts used as the starting point in scenario development and to the nature of the linkages between MEFS and NRIES. Linking the two models requires the construction of surrogate measures of physical output and capacity for particular energy products in order to derive marginal changes over baseline projections.

NRIES has been shown to be most easily adjusted to incorporate national (macroeconomic) rather than multi-state and state policy impacts. This property relates to model specification; NRIES state-level forecasts are partially dependent upon exogenously specified macroeconomic variables which are usually taken from macroeconomic projections generated by the Bureau of Economic Analysis. National policy impacts which are defined in terms of these macroeconomic variables are thus incorporated into NRIES simply through variable substitution. Conversely, state and multi-state policy impacts must typically be incorporated into NRIES by constant adjustment techniques, which require considerable familiarity with the model since changes

to equations are judgemental rather than according to well-defined methodological approaches. Because of this, state and multi-state direct impacts are likely to incorporate greater error than impacts associated with national scenarios.

Of the scenarios examined in this study, state and multi-state scenarios represented by the Montana Coal and AAR National Energy scenarios, respectively, have been found to exhibit the most policy-relevance with respect to the concerns of EIA.

(Energy policy enters the national (macroeconomic) scenario, which attempted to provide a framework for achieving greater consistency between aggregated NRIES and DRI forecasts, only to the extent that energy assumptions are used to drive DRI projections.)

Evaluation of the NRIES/DREEM framework in the context of these scenarios therefore appears most relevant. Below are discussed specific issues concerning the implementation of this framework which have been identified from data development efforts for the Montana Coal and AAR National Energy scenarios.

Clearly, a DREEM framework which uses NRIES for analyzing spatially defined facility development decisions, such as those hypothesized in the Montana Coal scenarios, is a feasible one. Plant-specific data can be generalized sufficiently to develop construction and operating costs and schedules which can then be converted to appropriate direct impact input data for NRIES. But the question remains whether NRIES is necessarily the best framework for analyzing state-level impacts. Although the model maintains a national context in state-level policy simulations and makes explicit the interstate linkages, NRIES lacks the sectoral detail which is usually required to comprehensively assess development impacts on the state's economy. A more important problem, however, relates to whether the model is being properly applied in state-level scenarios.

In the Montana Coal scenarios, materials inputs for the construction of hypothesized energy supply and conversion facilities were assumed to be imported from the rest of the U.S.

Given the nature of the state's economy, this is a reasonable assumption. But rather than diverting inputs from the rest of the economy, these materials inputs were assumed to be produced in addition to capital goods which would be produced in the absence of additional coal development in Montana (a baseline). Essentially, the national economy was boosted by an additional 188 million to 1.5 billion (1972) dollars over the 1977 to 1985 time period to supply materials input to Montana for constructing energy facilities in the three scenarios, creating extra-regional economic benefits¹ which are likely distorting regional impact estimates in Montana and all other states over the forecast period. The provision of a national context for undertaking state economic impact analysis may, in this case, be introducing considerably more error into economic forecasts than other (state-level) models which don't consider national linkages as explicitly. The assumptions implicit in altering the national economy to account for specific energy facility investments should be restated and re-examined in subsequent state-level applications of NRIES.

NRIES is clearly an appropriate model for assessing the distributional consequences of locationally-specific energy development activities since inter-state economic linkages are explicitly stated in the model's structure. The model is also well-suited for analyzing indirect impacts which are transmitted within multi-state regions for the same reason. But if policy impacts are examined at the state-level only, NRIES is less appropriate. More informative evaluations can likely be undertaken using models specific to the state being analyzed (see Chapter 3) which contain considerably more sectoral and sub-state detail than NRIES.

With respect to the multi-state scenario examined in this research effort, conceptually, using NRIES to determine the indirect and induced economic impacts associated with MEFS energy

¹ Presumably, the durables manufacturing sectors in all States in the U.S. were scaled to reflect this boost in the economy.

forecasts is far superior to the current procedure employed in EIA. That NRIES provides a better regional economic framework may be attributed to three characteristics of the multiregional model. First, NRIES incorporates considerably more economic, demographic and fiscal detail than EIA's current methodology, the Regional Earnings Impact System (REIS). Second, the model's bottom-up structure explicitly recognizes interstate linkages and can account for distributional changes in economic activity which can be associated with alternative energy supply and demand scenarios. REIS, on the other hand, is strictly a top-down methodology which estimates state economic impacts as shares of a national total. Impact estimates for one state are therefore determined independently of those for other states. Furthermore, state-shares are insensitive to changing energy supply and demand trajectories. A third characteristic of the model is that state-level forecasts can always be aggregated to derive national macroeconomic parameters. Thus, NRIES can be used iteratively to both drive MEFS energy projections and to calculate regional economic impacts associated with these projections to arrive at a set of consistent regional/national economic and energy forecasts for EIA's Annual Report to Congress.

However, severe methodological problems must still be resolved before MEFS and NRIES can be practically and consistently linked. The most formidable one relates to the establishment of appropriate baselines for determining the direct impacts implicit in MEFS forecasts, which is a necessary prerequisite for linkage. Alternative approaches which can be suggested are three. One is to disaggregate NRIES sectoral detail so that structural equations for each energy supply, conversion and transportation activity projected by MEFS exist for each state. This alternative would require considerable model development efforts on the part of BEA and is not currently being considered by developers of the model.

A second alternative, which was demonstrated in the previous

chapter, involves the construction of surrogate baselines from historical data which are essentially independent from the NRIES data base. Since NRIES sectoral definitions are too aggregate for developing trends, independent time-series data which are specific to the energy activities forecast by MEFS must be extrapolated to 1985 in this approach. The extrapolated forecast then constitutes the "baseline". Correspondence between NRIES forecasts and independent extrapolations is assumed on the basis that both projections are based upon the same estimation period (1956-1977). Problems with this approach have been outlined in considerable detail in Chapter 4 and relate to the necessary independence between energy activity forecasts implicit in NRIES' state sectoral projections (the actual baseline) and extrapolated estimates inferred from historical data.

A third approach, which has been suggested by BEA, requires that a baseline MEFS scenario be assumed. Here, that MEFS scenario judged to most closely approximate future energy supply and conversion production and capital investment levels implicit in the NRIES baseline forecast is designated as the MEFS baseline. Direct impacts associated with all other MEFS scenarios are then calculated using the designated MEFS baseline as the reference. Similar to the second approach, the baseline is derived inferentially since insufficient information exists in NRIES forecasts to calculate baselines directly. In this case, however, the selection process is more judgemental, and substantial experience and familiarity with NRIES is therefore required to ensure that all significant factors are considered in the designation of a baseline MEFS forecast. Note that in this case, the linkage, itself, is actually an implicit one and is more difficult to document in model application.

Because the linkages between the two models are obscure, considerable error can be expected to be introduced into direct impact estimates by either the second or third approaches, and this detracts from the usefulness of NRIES for assessing regional impacts associated with alternative MEFS forecasts.¹ Although a major source of error has been identified above, other errors

¹Note that NRIES' applicability in this context is further reduced by its abbreviated forecasting horizon. Forecasting only to 1985 precludes the model's use for analyzing 1990 and 1995 energy projections.

are likely to be introduced in region-to-state mappings and region-to-state allocations to NRIES economic sectors which are required to effect the transformation of MEFS forecasts to NRIES inputs. Clearly, a consistent, transparent conversion methodology must be developed to undertake regional economic analyses of comprehensive, multi-state energy policy scenarios, such as those forecast for the Annual Report to Congress, which can be considered both credible and reliable. Such a methodology cannot be considered to exist at present. Alternative methodologies for linking the two models should be further tested, evaluated, compared and documented in continuing research.

Application of NRIES in the DREEM framework has shown the model to be capable of addressing a variety of energy policy issues at difficult levels of spatial resolution. The model's versatility has enabled it to be applied to state, multi-state and national policy contexts although it has been suggested to be most appropriately applied to the analysis of multi-state issues, where problems in transforming direct impacts to data inputs have been found to be most acute. Further research is definitely required to determine whether multi-state energy policies, such as those embodied in MEFS forecasts, can be effectively linked to NRIES. But although this study has concentrated on just one analytical framework for estimating energy-related impacts, what is clear is that neither NRIES nor any other single model can be expected to meet all of EIA's policy evaluation needs. A DREEM framework should be a comprehensive one, involving several classes of models capable of addressing the range of policies which can affect regional economies. NRIES can clearly be made to provide some of this support. Further effort should be channelled towards determining what other analytical frameworks should be included in the DREEM construct and how they may best be applied.

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