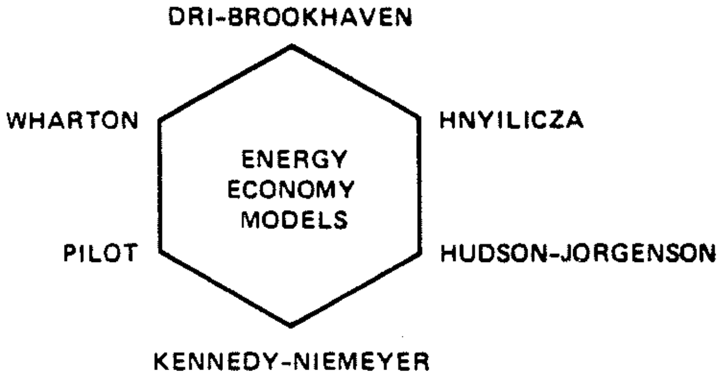
ENERGY AND THE ECONOMY



EMF Report 1
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September 1977

Energy Modeling Forum
Institute for Energy Studies
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EXECUTIVE SUMMARY

ENERGY AND THE ECONOMY

The Electric Power Research Institute created the Energy Modeling Forum (EMF) to improve the usefulness of energy models. Administered by the Stanford Institute for Energy Studies, the EMF operates through working groups of energy model developers and users conducting comparative tests of a variety of available energy models. To date, the EMF has completed one investigation--of the effects of changes in the energy sector on the domestic economy. Topics for future studies have been recommended by the EMF Senior Advisory Panel and further studies are in progress.

The first EMF working group, examining the link between energy and the economy, concentrated on the use of several large macroeconomic models as described in this report. Each model was represented in the working group by a technical team or expert. To compare the results obtained by these models, the working group developed a common set of assumptions and scenarios for analysis. Forecasts of absolute levels of output and energy consumption are not the focus of this study. Rather, the models are compared to uncover the differences or similarities in the estimates of the economic effects of changes in the energy sector, i.e., changes in relative energy prices or relative energy utilization.

The major conclusions derived from the models' output include:

- In the presence of constant energy prices, increases in economic activity produce similar increases in energy demands, although these may be moderated by trends toward less energy intensive products and services.

- Higher energy prices or reduced energy utilization need not produce proportional reductions in aggregate economic output. There is a potential for substituting capital and labor for energy and the contribution of energy to the economy, relative to these factors, is small.

- The models do show some substantial reductions in economic output resulting from higher energy prices. The magnitudes of these reductions are very sensitive to the substitution assumptions implicit in the models. Further, the impacts may be large for individual sectors of the economy.

- The benefits of energy substitution may be lost in part if energy scarcity impedes capital formation. Reduced energy inputs may cause lower levels of investment and, consequently, reduce potential GNP. This indirect impact may be the most important effect of energy scarcity.

In addition to the direct results of the models, the working group identified other conclusions concerning the strengths and weaknesses of the models and the methods they employ. The models are useful, each with different attractive features. The study of the impact of energy on individual economic sectors requires the use of the detailed models. The analytical processes applied by the EMF working group may assist in the use of these models. The development of simple approximations explains a model's structure and clarifies the important underlying assumptions. Despite their usefulness, however, the models simplify or exclude important characteristics of the link between energy and the economy. For example:

- All the models examined focus on the long run potential of the economy. Abrupt changes in energy availability or other policies with short term implications may affect the realization of this potential GNP, but are not within the scope of the models studied here.

- The models require assumptions about future population or labor force growth and the rate of technological change which, other things equal, determine the growth path of the GNP. The analysis in this study is directed at the changes in growth due to changes in the relative scarcity of energy, not to absolute levels of future economic activity. There may be some effect of energy price or availability on the variables whose values are here assumed. Any such effects would not be captured in the models.

- The representation of nonmarket behavior is difficult to include in the models. The effects of regulation, industrial organization, or the expectations created by government's future role are not well understood.

- The models treat environmental considerations in a rudimentary way. They do not address the causes and effects of persistent unemployment nor the impacts of unexpected embargoes. Financial sectors are highly stylized or absent in many of the models. Such important issues require different analytical approaches or major model extensions.

TABLE OF CONTENTS

Volume 2 Appendices:

LIST OF TABLES

Volume 2

LIST OF FIGURES

Figure Page

Volume 1

Volume 2

Page

F-6 Total Quads:

F-11 Energy-GNP Ratio:

F-16 Normalized Energy-GNP Ratio

F-20 Energy Imports:

F-25 Fossil Fuel Price:

F-30 Energy Consumption Per Capita:

F-36 GNP Effects of Constraints:

F-42 Elephant-Rabbit Comparison:

LIST OF TECHNICAL MEMOS

Technical
Memo | Page

Volume 2

ACKNOWLEDGMENTS

The composition of the working group was intended to be heterogeneous, and the contributions of the members display a similar variety. The modeling teams gave much of their own energy to the implementation of the frequently modified set of comparative scenarios. Other members contributed to the analysis of results or the preparation of the report in its several sections. Where possible, as in some of the appendices, individual authors are identified and individual responsibility is accepted. However, the main section of the report, Volume 1, represents the combined efforts of too many members of the working group to properly identify individual authors. While the working group is in general agreement on this report, not every member necessarily agrees with every statement. The responsibility for any remaining errors rests with the working group chairman. I thank all the members of the working group for their help and patience.

I offer particular thanks to Shailendra Parikh of Stanford for his tireless efforts. I express my special appreciation to Larida Stacy who, with the assistance of Joanne Eiseman and Donald Long, was responsible for the typing of many drafts of these reports and the complicated management of our paper flow. In addition, I thank Dennis Fromholzer who provided the computer support, Dorothy Sheffield for her editorial assistance, and John Riddell for his help at our first meeting.

I also thank the Electric Power Research Institute (EPRI) for its financial and moral support and the Stanford Institute for Energy Studies for its continuing assistance. Finally, I want to express my gratitude to Martin Greenberger who as the EPRI program manager has displayed an extraordinary interest in this project and made a significant personal contribution to its success.

William W. Hogan
Working Group Chairman
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September 1977

ENERGY MODELING FORUM

SENIOR ADVISORY PANEL

The Energy Modeling Forum seeks to improve the usefulness of energy models by conducting comparative tests of models in the study of key energy issues. The success of the Forum depends upon the selection of important study topics, the broad involvement of policy makers, and the persistent attention to the goal of improved communication. The EMF is assisted in these matters by a Senior Advisory Panel that recommends topics for investigation, critiques the studies, guides the operations of the project, and helps communicate the results to the energy policy making community. The role of the Panel is strictly advisory. The Panel is not responsible for the results of individual EMF working group studies.

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ENERGY AND THE ECONOMY
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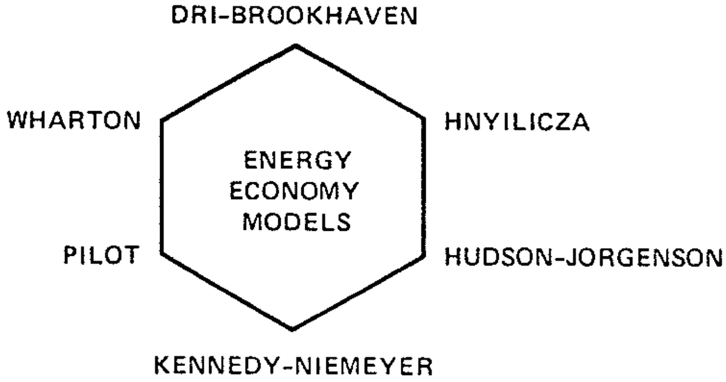
Volume 1

ENERGY AND THE ECONOMY



ENERGY AND THE ECONOMY

INTRODUCTION

Energy use and the economy have grown together.

During recent decades, the national economy has produced a substantial rise in output. Energy consumption has experienced a similar increase. Between 1950 and 1973, the economy grew at 3.6% per year while energy consumption grew at 3.4% per year. It is natural to attribute a causal relationship to these patterns. Expansion of the economy raises energy consumption, and a plentiful energy supply is seen as a spur to economic growth. The common expectation, however, is that future energy supplies will be limited and expensive. This new perception of the energy situation has created a call for national action. If abundant energy is essential for future economic well being, a large effort is required now to guarantee that our needs are proper and are properly met.

But does economic growth depend on energy availability?

At the root of this national concern is the assessment of the dependence of the economy on energy. This is a complex problem. Energy availability affects every facet of our economy and energy is used in many different forms. What may be true for the use of electric power in aluminum production need not be true for the use of oil in home heating. Regional differences, the long lead times for major changes in facilities, and the uncertainties of the security of supply contribute to the difficulty of describing the interface between the energy sector and the remainder of the economy. It is not surprising, therefore, that there is a diversity of opinion about the nature and importance of energy-economic interactions. There is some evidence that the relationship between energy and economic growth is not immutable, but the degree of potential flexibility is disputed.

Are forecasts and other energy studies valid that do not include the possibility of such dependence?

The ramifications of large interactions are wider than it may seem at first glance. Energy forecasts are based customarily on projections of the future output of the economy. Suppose that this output is altered by the feedback effect from changes in the supply and price of energy. Then the energy forecasts themselves may be inconsistent. Thus, the magnitude of the energy-economic feedback bears on the validity of analytical studies that isolate the energy sector from the remainder of the economy. Such isolation affords an enormous simplification of analysis and is engaged in to some extent by most energy studies.[1]

The Forum is comparing runs of a variety of energy models to explore these questions.

It follows that analysis of the energy-economic interactions must precede evaluation of energy options. The purpose of this report is to summarize the Energy Modeling Forum's study of selected models of energy and the economy. These models come equipped with an ample set of limitations, and their use is qualified by the usual caveats. Some of these are discussed in the report or the appendices. The reader will recognize the narrow scope of this analysis in examining GNP and prices as the representatives of economic activity to the exclusion of environmental issues, problems of income distribution, changes in international trade, or a host of related subjects. In part this is caused by the intent to compare results across models and the need to limit the scope of the study. The detailed models have rich structures, and many can be applied to a wider spectrum of issues than is considered here. However, the limited questions addressed in this study are important and the model comparison illuminates several valuable conclusions. Early on, the analysis rejects the straw man of a lockstep linkage between energy and the economy. Reductions in energy utilization need not produce proportional reductions in economic activity. The small value share of energy in the total economy is shown to be an important but incomplete component of this story. It is the potential for substitution that dominates this analysis and establishes the

The value of energy input is small compared to the total economy.

importance of large changes in energy availability in determining the resulting changes in economic activity. The final theme centers on the indirect effects of energy on capital, which may compromise some of the benefits of substitution.

The paper begins with the history of the Energy Modeling Forum. After describing the role of energy models, the paper develops some fundamental concepts that help explain the structure of the models used in this study. The paper concludes with a comparison of model results and their implications for the evaluation of the energy-economic interactions. Details of the analysis and relevant supporting material are left to a series of appendices.

THE ENERGY MODELING FORUM

The expanding number of energy models provides a framework for analysis and debate.

Behind sharp disagreements on energy questions, there are often simple but fundamental differences in views about the nature of the problem. If made explicit, these alternate views can be compared and evaluated. Formal models implemented on computers provide a capability for organizing and extending the debate about the impacts of future energy alternatives. In many settings, energy models are integrated into the specification and evaluation of energy options, but their full potential is not being realized. The sudden increase in energy policy concern has produced an expansion of energy model development effort, but these new capabilities are not widely understood and are not applied to many relevant energy problems.

But these models must be better understood through the improved communication the Forum provides.

If energy models are to contribute to the improvement of the energy policy debate, there must develop a wider appreciation of current model capabilities and a better specification of model limitations needing new research. This presumes regular communication between the developers of energy models and potential users. To meet this need, the Electric Power Research Institute is sponsoring the Energy Modeling

Forum, a project administered through the Stanford Institute for Energy Studies. The purpose of the Energy Modeling Forum (EMF) is to promote communication between model users and developers through the comparative application of current energy models to the analysis of priority energy issues. Disciplined by the focus on a specific question of importance, the EMF operates as a combined group of energy model developers and model users. By structuring comparative tests, the EMF seeks to clarify the central implications of the models and the assumptions on which these results are based. In the process, common perceptions of energy problems emerge, new priorities for analysis are identified, and the uses of the models are illustrated.

The Forum's pilot study concerns the relationship between energy and the economy.

The first EMF working group was organized to develop operating principles and demonstrate the viability of the basic concept. For its initial study, the group examined the link between the energy sector and the economy. What is the nature of the link between the energy sector and the remainder of the economy? How strong are the feedbacks? Will changes in energy utilization have a significant effect on the future of the economy?

Can the use of energy be diminished without affecting output?

The relationship between the energy sector and the economy is central to the evaluation of energy options. Most concern with energy issues arises from the assumption that the character of future energy availability will have a major impact on the quality of life, and the level of economic activity is a primary measure of this quality. Opinion is divided sharply on the structure of the link between energy and the economy. Basic physical laws indicate that some energy is required for every activity and if adequate energy is not available the activity cannot take place. From this perspective, the historical growth of energy and the economy is cited as evidence that their future growth cannot be separated. In the short run, most would agree, for we must use the equipment and processes now in place, and their range of energy utilization is narrowly restricted. In the longer run, however, new equipment can be purchased, alternate transportation systems designed, the mix of desirable products changed, and new technology introduced. The same level of output might be obtained with a lower level of energy utilization and the quality of life maintained or even improved, some would say. This perspective is supported by the evidence of different energy utilization patterns and higher energy prices in other industrial nations. The history of low energy prices may explain the growth of energy demand in the United States.

The answer is central to future policy choices.

If growth in energy availability is essential to the growth of the economy, then large expenditures are indicated for programs directed at expanding long run energy supply and lowering energy costs. However, if substantial flexibility exists for adjusting energy utilization and economic output, then programs which facilitate this adjustment may be employed. The best policy probably requires a careful blending of both approaches, but it is certain that these choices will be influenced heavily by the expectations of the impacts on future economic growth. It is essential to understand the links between energy and the economy.

THE ROLE OF MODELS

Computer modeling allows pieces of a problem to be analyzed separately, then combined.

Energy models alone cannot dispose of these difficult issues. They augment our capabilities for organizing the collective understanding of a problem. Modeling does not replace careful thinking, but seeks to exploit it. A model records what we know by providing an accounting framework, organizing the data and key relationships. At the heart of most models is some simple classification scheme. For example, the model may describe all energy consumption in terms of a few sectors, aggregating the millions of households, commercial establishments, or industries. This permits the separate but consistent analysis of the major problem components. Specifying how these components connect may simplify other complex interactions.

Hence, one analysis may characterize the effect of regulation on the supply of natural gas. A separate analysis of substitution relates the supply of natural gas to the industrial demand for oil. When combined, the two analyses are a model of the relationship between regulation and the industrial demand for oil. In the process of specifying each analysis and the interface, the important assumptions are illuminated and made easier to validate. Is it true that oil and gas are perfect substitutes in all industries? If not, how sensitive is this assumption in the estimation of the effect of regulation on the industrial demand for oil? If the model is explicit, these questions can be addressed systematically. The implications of a given hypothesis about the structure of the energy system can be pursued. If the model also is detailed, computer implementation may be a further aid in pursuing the needed calculation. These contributions of modeling are substantial. The accumulation of knowledge and the pursuit of the implications of that knowledge are the essence of sound analysis. Formal modeling makes the process explicit and promotes its orderly evolution.

But models are at best only simplified approximations of reality.

The limitations of models are important to recognize. The basic limits of our understanding are transferred to a model. Hence, the effects of noncompetitive practices are not to be found in the study of models assuming perfect competition. A model does not create a new theory, it explores the existing theory, often in a highly simplifed fashion. This simplification is essential in modeling, permitting quick analysis of many relationships and the clarification of basic causal mechanisms. Without simplification, the only model of reality is reality itself, and only one experiment is permitted. With a model, many experiments are possible. And, unlike reality, we can take them or leave them. But the model is only an approximation to reality and must be judged accordingly. Many approximations to the same reality are possible. The application of any one model must be guided by the context of the questions addressed. For problems as complex as the evaluation of energy futures, there is no single model which addresses all issues. There are many problems for which there are no models at all. Energy models do not replace the effort of the analyst in determining the appropriate assumptions and problem structure, but they do extend the scope of the problems that can be studied.

We start with a simple model. It can be extended as its deficiencies become clear.

The benefits of simplification and the potential for detail are found in the range of available models of energy-economic interactions. Very simple aggregate analyses of the interaction can place the problem in perspective. These aggregate models provide the conceptual background for the evolution of more sophisticated systems. As the potential deficiencies of the simple models are identified and the assumptions relaxed, more detailed models develop and the range of application expands. Therefore, before presenting the results of the sophisticated models participating in the EMF study, a basic framework is developed for characterizing the key concepts underlying the interaction between the energy sector and the economy.

A BEGINNING FRAMEWORK FOR ANALYZING ENERGY AND THE ECONOMY

The issue here is the impact of a relative scarcity of energy. None of the models implies that energy is not needed for the economy. If energy prices remain stable, then an increase in economic activity should produce an increase in the demand for energy. Of course, the future growth of energy demand may be less than the historical growth because of lower projections for population increase or a trend toward a disproportionately higher growth of the less energy intensive sectors of the economy. The difficult question is, can energy demand growth be dampened further by higher energy prices without proportional reductions in economic activity?

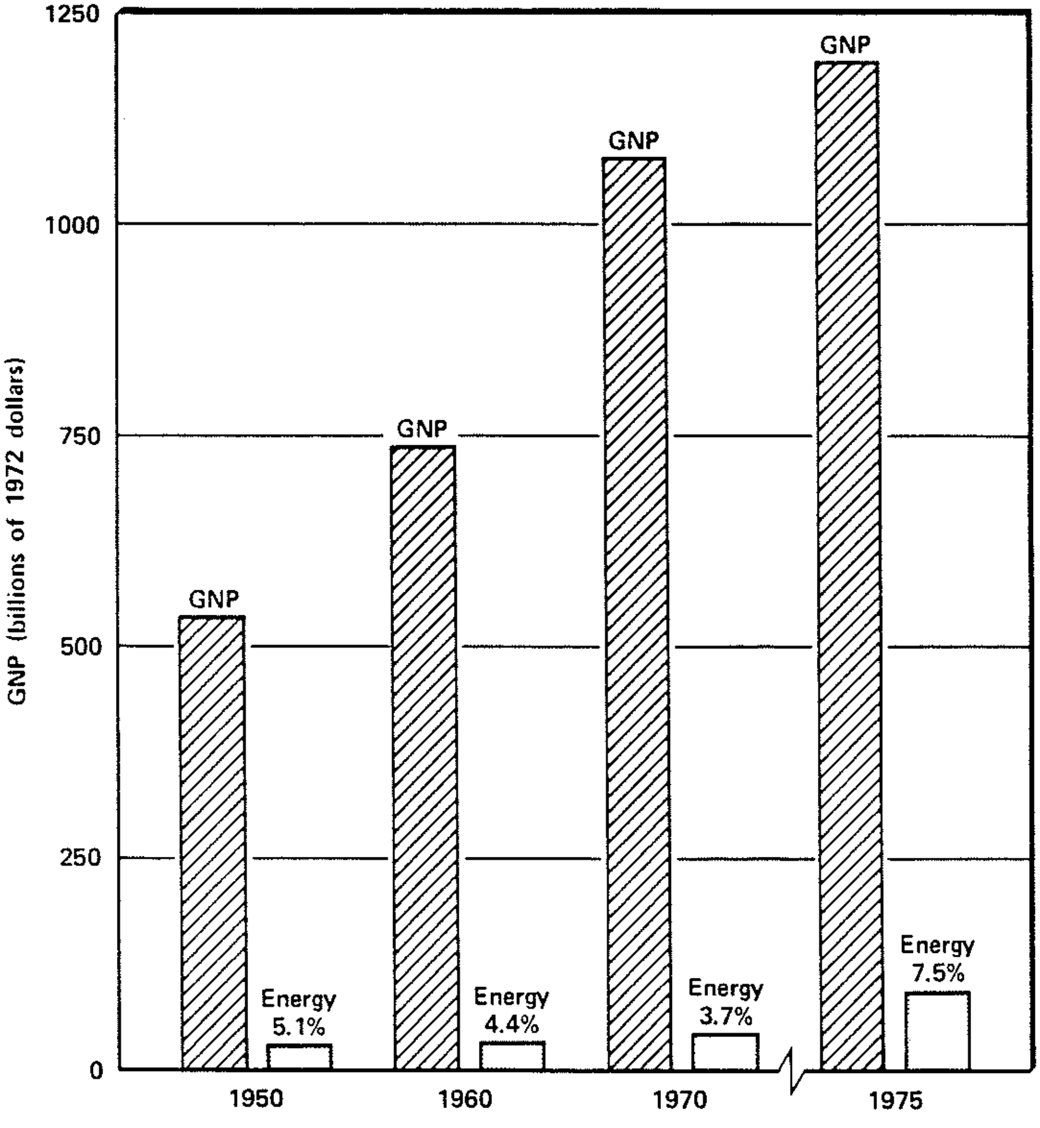
The value of energy input is small compared to the total enconomy.

For simplicity, we restrict attention to the long run, when energy equipment and processes can be changed substantially. In the short run, the character of the problem is different and different models are appropriate. As a further simplification for this beginning discussion, we represent the economy in terms of just two inputs--energy and all other items. Note in Figure 1 that energy is only a small component of the total U.S. economy. As of 1970, the value of primary energy inputs did not exceed 4% of the GNP. The analogy of an elephant-rabbit stew illustrates the implications of this low value share. If the recipe for such a stew calls for just one rabbit (the energy sector) and one elephant (the rest of the economy), won't it still taste very much like elephant stew?

Hence, changes in energy choices need not dominate future economic activity.

If energy prices had not risen after 1970, it is likely that energy demands would have grown at about the same rate as the GNP. The 4% ratio would then continue into the future. But what is the effect when energy costs double and there is sufficient time for the economy to adapt? One estimate of the impact may be obtained by assuming a constant recipe. Suppose the rabbit is paid for with part of the stew. Then an additional 4% of the stew (GNP) must be allocated to cover the doubling in the cost of the rabbit (energy). In fact, other recipes are available that call for less rabbit and, therefore, lead to lower costs. Under these assumptions, the first doubling of energy costs would produce, at most, a 4% loss in GNP.

With a more complicated argument, it can be shown that a small decrease in energy supply leads to a decrease in economic output proportional to the value share of energy in the economy. At a 4% value share, a 1% reduction in energy input would produce a 0.04% drop in total output. By this argument, a small percentage change in energy availability produces a considerably smaller percentage impact upon the economy as a whole.[2]



SOURCE: See Note 3.

Figure 1 GNP and Energy

The degree of potential substitution determines the importance of energy.

This simple analysis provides some insight but it suffers from a major defect in failing to represent accurately the flexibility of energy utilization in the economy. The processes for future production and utilization of energy are not fixed immutably. Insulation, efficiency improvements, and changes in the mix of input factors can alter the energy requirements for a fixed level of output. Such substitution possibilities can modify the economic impact of changes in the energy system. Flexibility in energy utilization is a central factor in determining energy-economic feedback, and its treatment varies widely among the many different energy models.

THE ROLE OF SUBSTITUTION

The aggregate measure of substitution is similar to the elasticity of demand.

The specific processes for energy substitution may be varied and intricate. Therefore, even if it is generally agreed that some substitution is feasible, it may not always be possible to identify the specific technological options available. The morass of detail may be approached gradually by expanding our first simple model and the beginning arguments based on the value share of energy. We explicitly assume now that substitution is possible between energy and nonenergy inputs to the economy. For the purpose of the present discussion, this flexibility can be summarized in economists' terms as the elasticity of substitution. Ignoring the feedback to the economy or other inputs, this parameter is the same as the elasticity of energy demand. It measures the proportional response of energy demand to a change in energy prices. Hence, if the elasticity of demand is -0.3, a 10% increase in energy prices produces a 3% decrease in energy demand.

The elasticity of substitution is the index of aggregate model behavior.

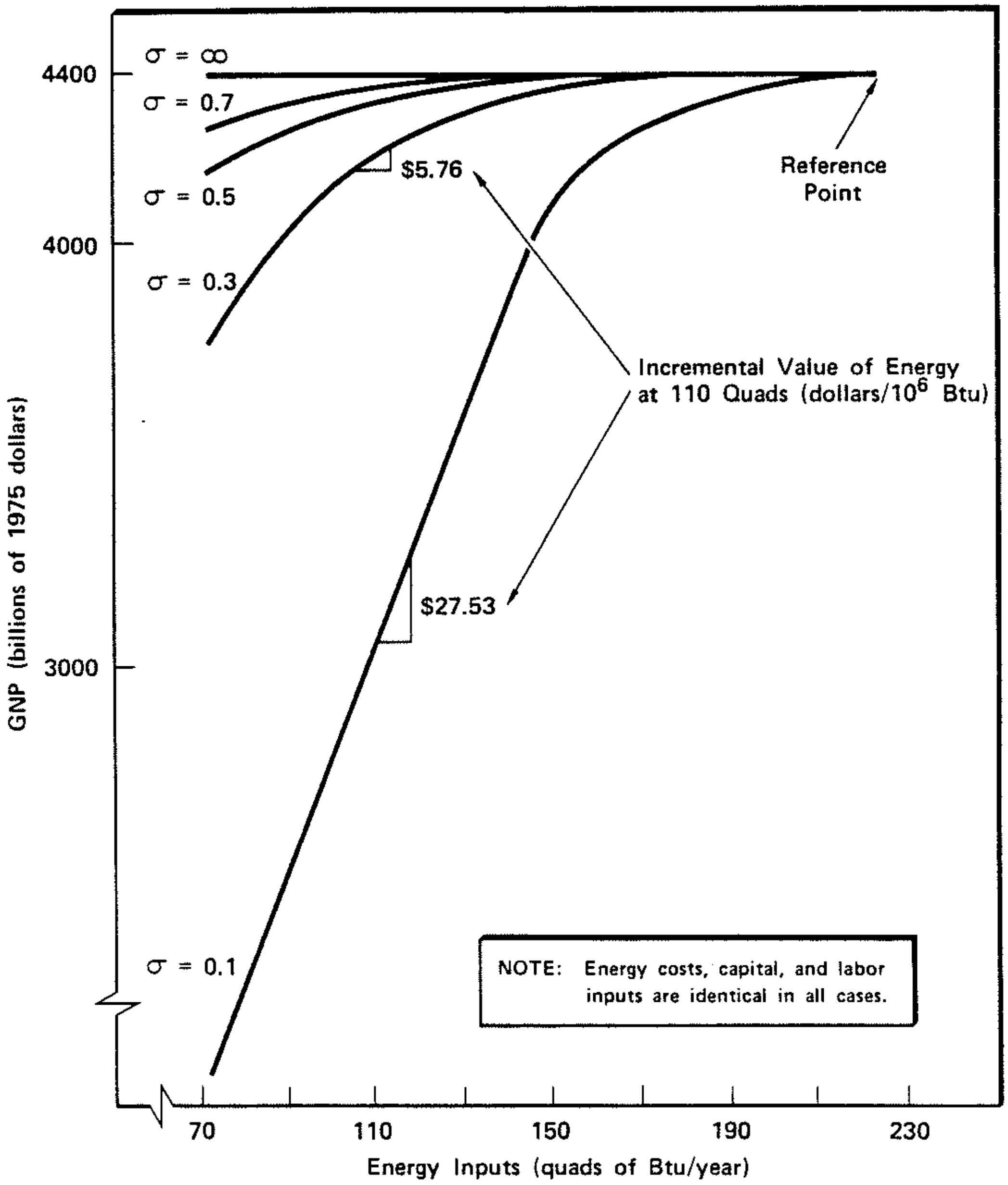
This concept, the elasticity of substitution, provides a convenient index for summarizing the aggregate behavior of the detailed models. If we assume that inputs of other factors such as capital and labor are held constant, then the elasticity of substitution virtually determines the feedback effect of the energy sector on the rest of the economy. The implications of alternate elasticity estimates are shown in Figure 2. This depicts the GNP in the year 2010 as a function of energy input, holding other inputs constant. It is assumed that a Btu tax is imposed gradually to reduce energy consumption. Such a tax might be levied, for example, to mitigate environmental impacts or lessen import vulnerability.[2]

The analysis is based on a hypothetical reference forecast, but the qualitative conclusions are not sensitive to this reference. A small change in energy availability has almost no effect on GNP. The loss in output is exactly balanced by the savings from the reduced expense of energy. This is what the price represents, the value of the product at the margin. This value will change as the quantity of energy input changes but the output does not decrease in proportion to the decrease in energy input. Substitution of other input factors compensates for the reduction in energy input.

Seemingly small changes in the elasticity of substitution produce major changes in economic impact.

The importance of the long run elasticity of substitution is startling in the context of this analysis. A 50% reduction in energy availability produces a 28% reduction in GNP if the elasticity is as low as 0.1, but only a 1% reduction in GNP if the elasticity is as high as 0.7. Seemingly small changes in the substitution potential produce major changes in economic impact. Even the smaller GNP reductions have a large value, however. If the economy is growing at 3% in real terms and we discount future consumption at 6%, a 1% reduction in annual GNP corresponds to a present value of nearly half a trillion dollars. This is only 1% of the present value of future output, but it would justify a substantial research investment aimed at developing low cost technologies which can expand energy supply or improve the efficiency of energy utilization.

An alternative indicator of the economic impact of energy scarcity is found in the implicit tax associated with a given energy reduction. As a measure of the marginal value



SOURCE: See Note 2.

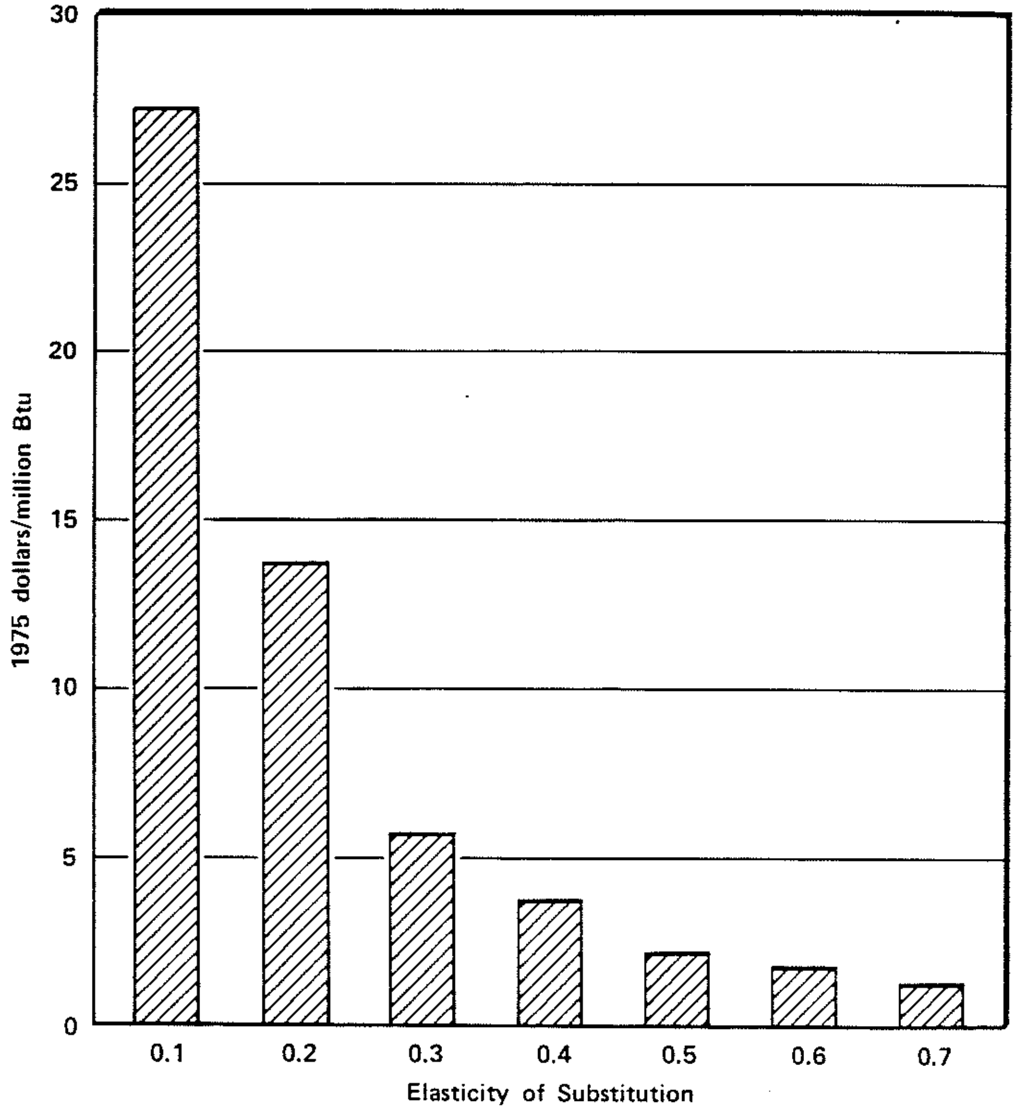
Figure 2 Economic Impacts of Energy Reductions in the Year 2010 for Various Elasticities of Substitution (σ) of energy, this tax may be a more appropriate barometer of the importance of energy scarcity. Although the specific tax is determined by the arbitrary assumptions of the reference forecast, the sensitivity to changes in the elasticity of substitution repeats the results of the analysis of GNP. The implicit tax for the 50% energy reduction from the reference forecast is shown in Figure 3. If the elasticity of substitution is as low as 0.1, the necessary tax is $27.53/million Btu, a tax of over 3400%. But if the elasticity of substitution is as high as 0.7, the tax is reduced to $1.26/million Btu or 158%.

Available estimates of the elasticity of substitution suggest some flexibility in the economy.

What is the proper elasticity of substitution? The estimation of this parameter has been the subject of many studies but there is no definitive resolution of the issue.[4] There are difficulties in comparing definitions, problematical data, and disputes about the relevance of past experience in extrapolations to the future. A consistent interpretation of these studies indicates the elasticity of substitution is between 0.2 and 0.6, although there is evidence for higher and lower values. As we see below, the detailed models which have an explicit representation of the full economy yield values between 0.3 and 0.5 for the elasticity as defined here, in terms of primary energy prices. This indicates that there is substantial but not unlimited flexibility in energy utilization in these models.

The benefits of substitution may be lost in part if investment is curtailed.

The estimates in Figure 2 of the impact of energy reductions are based on a simplified, partial analysis of the economy. This shows the potential of substitution between economic inputs to absorb energy input reductions with less than proportionate reductions in economic activity. However, changes in energy input have a further dimension of feedback to the economy. This additional dimension centers on the pattern of capital investment over time. Reductions in energy input lead to changes in the rate of return on capital as well as reductions in the level of total output. Investment, savings, and capital use are altered as a consequence. Over time, these



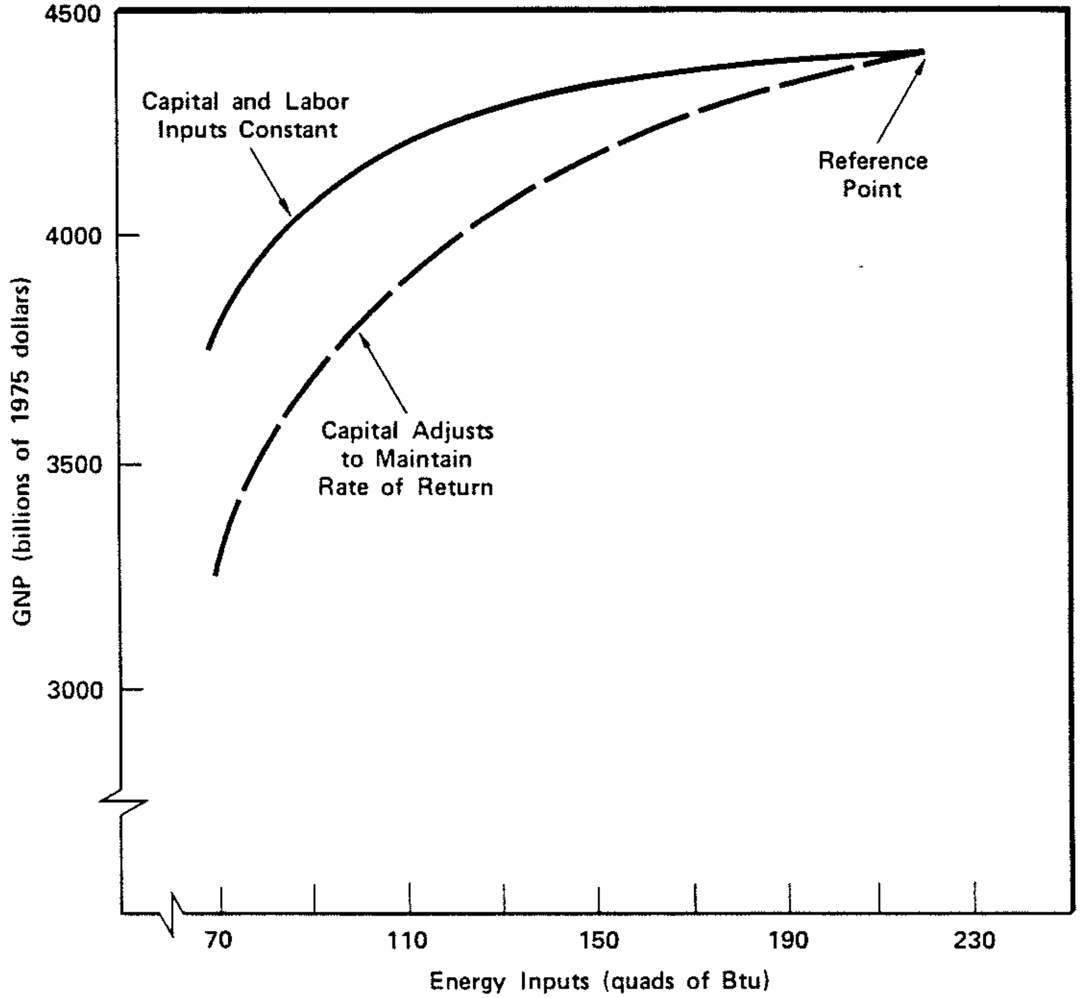
SOURCE: See Note 2.

Figure 3 Implicit Tax, Cutting Energy Use in Half by 2010 effects may cumulate into significant changes in the capital stock and, therefore, in the productive capacity of the economy. It is difficult to analyze these complex interactions; in fact the sophisticated models participating in this EMF study are required for this task. As an approximation, however, we can extend the partial analysis to illustrate the magnitude of the economic effects of changes in capital input. For this purpose, expand the beginning framework to include three economic inputs--energy, capital, and labor. Now, instead of holding capital and labor constant as energy input changes, let capital adjust to maintain a constant rate of return. The impact of this new assumption, for the case of an elasticity of substitution of 0.3, is displayed in Figure 4. For a 50% reduction in energy input, there is a 4% reduction in GNP when capital is held constant, but the reduction is 11% of GNP when energy is reduced and capital changes to maintain a constant rate of return. In this case, the capital change effect exceeds the direct effect of the energy reduction.[5] Thus both substitution and capital adjustment processes are important in considering the feedback effects of energy on the economy. When both these processes are taken into account the conclusion remains that while energy reductions do have a substantial economic impact, the GNP reduction is proportionally smaller than the reduction in energy output.

THE REAL MODELS

More detailed models can improve the representation of the substitution potential.

Several immediate difficulties can be found in the aggregate analysis of the preceding section. First, the aggregation itself may disguise distinctly different behavior in component economic sectors. This behavior is of interest in itself and can be captured only by more detailed models. Second, the aggregate substitution parameter does not provide a description of the new processes and technologies that must be adopted. Again, more disaggregated analysis is necessary to provide the detail to support the credibility of the simple analysis. Third, investment, savings, and capital accumulation might be affected by the price and availability of energy. Here is another reason for the construction of more sophisticated models.



SOURCE: See Note 2.

Figure 4 Economic Impact of Energy Scarcity in the Year 2010 for Alternate Capital Assumptions (Elasticity of Substitution $\sigma = 0.3$)

The detail in the participating models covers a wide range.

Increased detail is characteristic of most of the analytical extensions in the models included in the EMF analysis.[6] The most aggregate of these models, developed by Hnyilicza of MIT, organizes production around the inputs of four factors to produce energy and nonenergy outputs. Markets balance supply and demand in each period as the system evolves over time. The parameters of this model have been empirically estimated. It provides, therefore, a first estimate of the potential flexibility of energy utilization. This also serves as a reference for comparing the results of more disaggregate models.

At the next level of detail, found in the models of Hudson-Jorgenson and Kennedy-Niemeyer, the economy is divided into nine sectors with special attention focused on a variety of energy products. A richer array of production and utilization arrangements becomes possible in these models. When aggregated to the level of the beginning analysis, these models may provide a means for representing variable elasticities of substitution.

This detail is pursued further in the PILOT model of Stanford, the Wharton model, and the DRI-Brookhaven system. The range is from the 23 sector economy in PILOT to the 100 sector economy in the DRI-Brookhaven model.

Each of these models is too complex to comprehend in its entirety except by analysis of individual components and the rules for combining these components. This complexity is a cost of credibly representing the flexibility of energy utilization. Computer implementation permits rapid calculation and examination of the models' implications. And the results can be aggregated to the level of the simpler framework. For example, the elasticity of substitution is shown in the simpler framework to be an important summary measure in determining the economic impact of energy system changes. This insight can be applied to the comparison of the detailed models if we identify them in terms of their substitution assumptions.

The models extend from assumptions of little flexibility to substantial substitution possibilities.

When viewed from the perspective of energy substitution assumptions, the participating models may be divided into two categories. Two models, the Kennedy-Niemeyer and PILOT systems, employ structures which implicitly assume little flexibility in energy utilization. Later we shall see that their results are consistent with the first discussion of a fixed recipe in the elephant-rabbit stew. The remaining models employ structures which can incorporate substitution between energy and other factors. In addition, the parameters for the major components of these models are estimated empirically and, when aggregated, provide alternate estimates of the elasticity of substitution. We shall see that their aggregate behavior is consistent with the results of the simple framework.

Six test scenarios were run.

Six test scenarios were designed for these models. These scenarios are not intended as forecasts. To achieve some consistency, the working group compromised individual judgments as to the most likely futures. The scenarios are designed, instead, to display the feedback links embedded in the models. The details of the scenarios are explained in an appendix.[7] They cover different economic growth assumptions and examine severe reductions in energy availability or increases in energy costs.

The models assume long run full employment.

The comparison of the model structures and the design of the test scenarios reveal important assumptions common to all the participating models. Because of their focus on long run considerations, the impacts of temporary unemployment are ignored in all but the Wharton model. The economy is assumed to move quickly to a predetermined full employment growth path. The models concentrate on the evaluation of potential GNP. Hence, the models are not suited to the evaluation of policies which may produce persistent unemployment, nor are they suited to the study of unanticipated energy supply interruptions. These are major areas of policy concern, but beyond the scope of the participating models.

Standardized population and productivity assumptions determine a common GNP growth pattern.

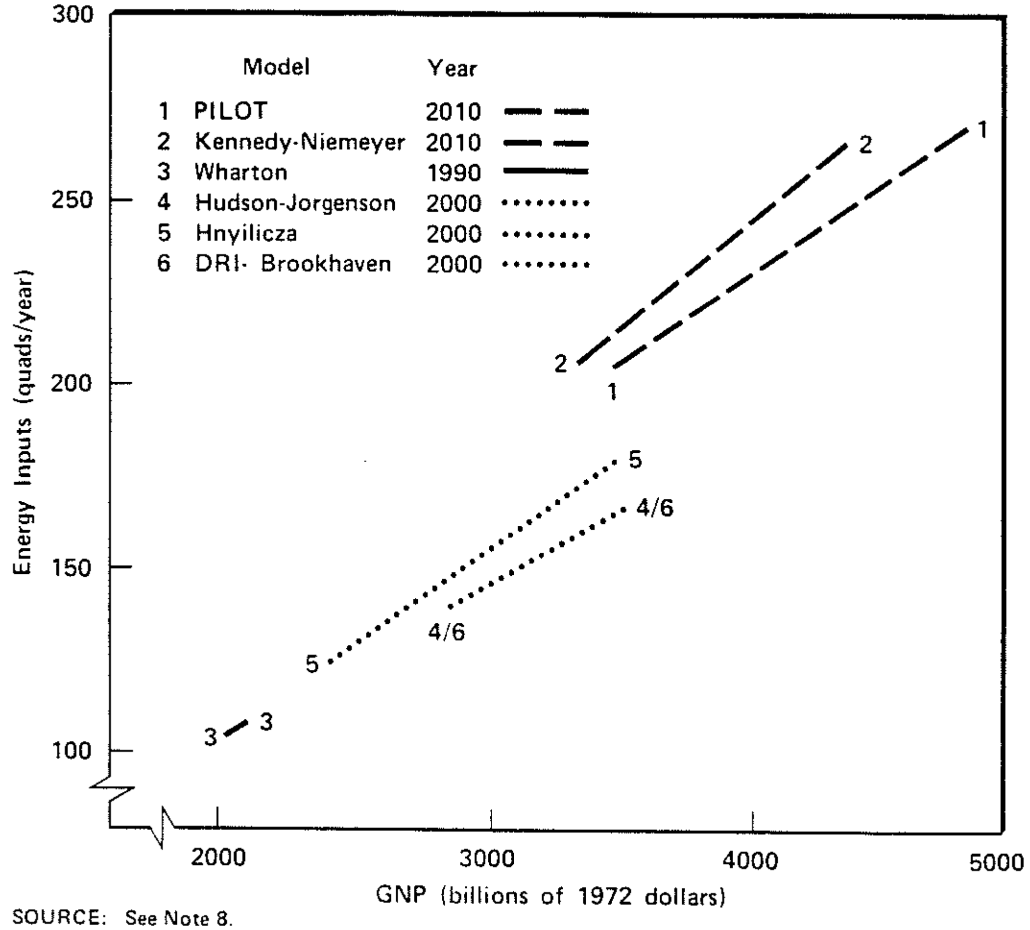
The importance of the full employment assumption is illustrated by the fact that all the models require as input the rates of population growth and productivity increase. The rate of population growth virtually determines the growth in the labor force. The rate of productivity increase describes the temporal improvement of technology which expands output for a given level of input factors. If the availability of other factors is not changing, then the growth in productivity plus the growth of employment must determine the growth of the GNP. In the presence of constant factor prices, therefore, the rate of GNP growth is an assumption in the models. A base case scenario standardizes the population and productivity inputs. All the models then produce the same growth path for GNP. The models are designed to examine the feedback from the energy sector to the economy, but they are not intended to provide a reference economic forecast.

THE MODEL COMPARISON

Four of the scenarios designed to test the models provide insight into the measure of the interdependence between energy and the economy. In addition to the base case, a high economic growth scenario is constructed by employing higher growth rates for population and productivity. These two alternate economic forecasts then are subjected to a collection of energy constraints designed to severely restrict energy supply, substantially increase energy prices, and produce curtailments of economic output.

With stable energy costs, increased economic activity produces increased energy demand.

The comparison between the base case and high growth case provides insight into the structure of the models. The role of flexibility in energy utilization and the impact of energy sector changes on the economy should not be confused with the direct effects of the economy on energy demand. Energy utilization may vary in the presence of changing energy costs. But when energy prices remain nearly stable, it is reasonable to expect economic growth to produce a growth in energy demand. A test of the models in this regard is contained in the comparison of the base case and the high growth case runs. The results confirm that all the models possess this expected property, some by assumption, others through parameters estimated empirically. Figure 5 compares the base and high growth cases in terms of energy input and economic activity for each of the models.



SOURCE: See Note 8.

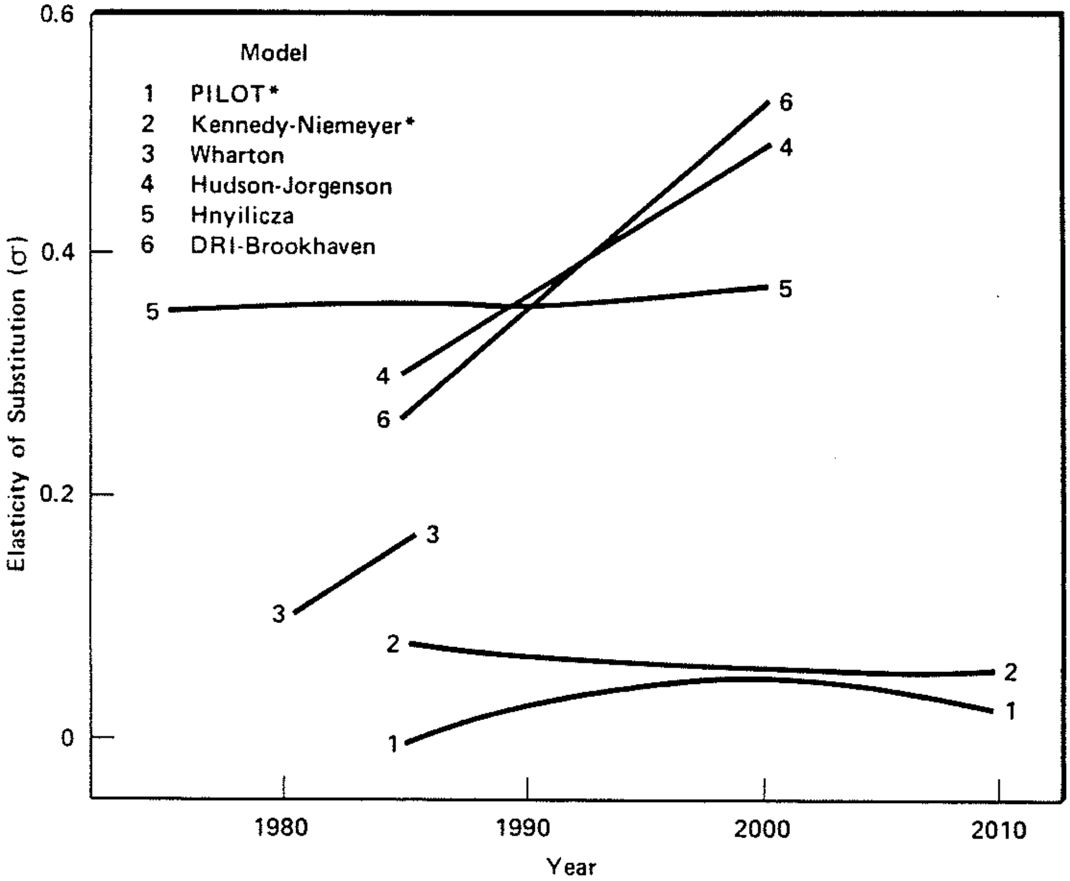
Figure 5 Energy Response to Economic Activity (Energy Requirements Given GNP in the Base and High Growth Cases)

Increasing energy costs may weaken the link between economic activity and energy demand.

When all other things are not held equal and energy constraints are imposed, both the utilization of energy and the growth of the economy may be affected. If the potential for energy substitution is low, the imposition of severe energy constraints should produce high energy prices and large reductions in output, maintaining a nearly constant ratio of energy input to economic output. If the potential for energy substitution is high, the energy constraints will have less effect on prices and output, and should produce a marked change in the energy-output ratio.

The base case and the high growth scenarios with and without energy constraints, or Btu taxes, provide tests of the feedback effect embedded in the various models. The estimates of the aggregate elasticity of substitution in each model are shown in Figure 6 for the base case. The implicit elasticities in the models need not be constant over time nor for different levels of price changes. In fact, the sophisticated models include many avenues for variation in the substitution potential. But the aggregate elasticity remains as a useful summary index of the models' behavior. These results confirm the earlier classification of the models into those which assume limited substitution and those which employ a structure designed to capture the potential substitution empirically. Both the Kennedy-Niemeyer and the PILOT models, which assume limited substitution, display aggregate elasticities below 0.1 and generally close to zero. The remaining models, which include detailed substitution possibilities, trend toward long run aggregate elasticities between 0.3 and 0.5. From the previous discussion, this range of substitution potential is seen to include substantial but not unlimited flexibility in energy use.

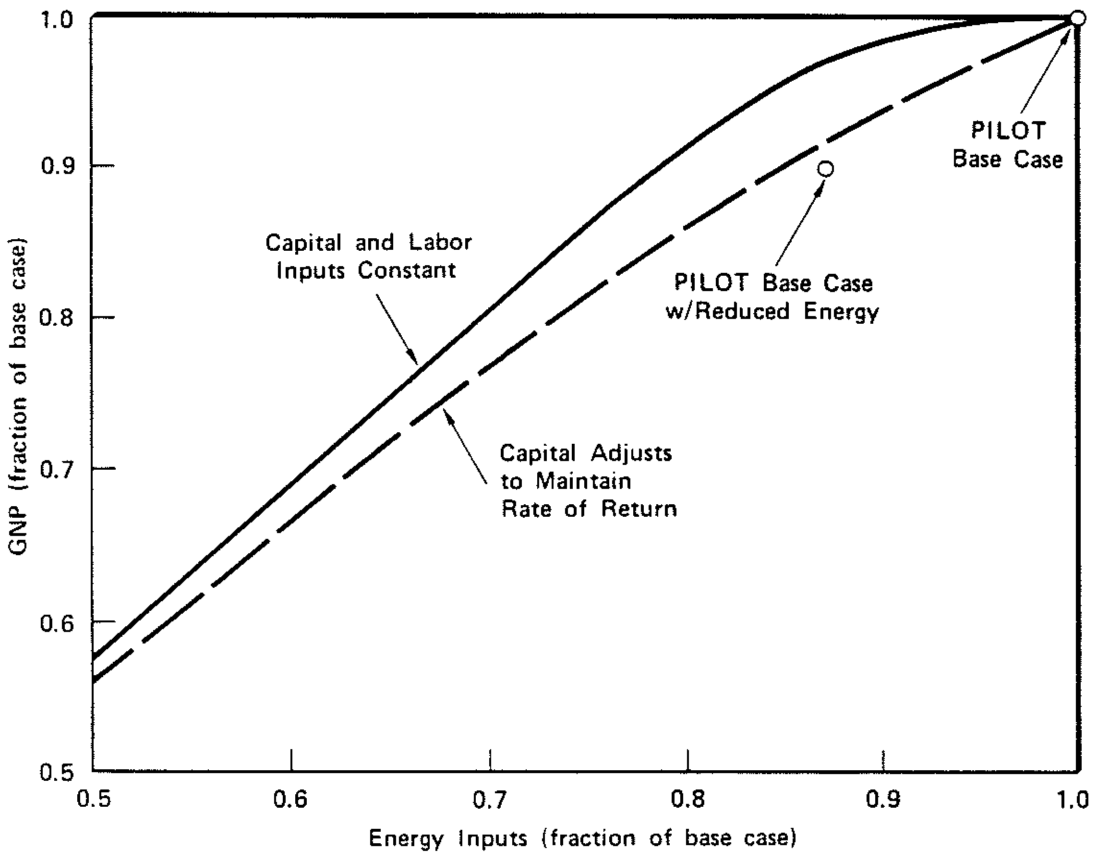
The value of the aggregate analysis in summarizing the results of the detailed models is illustrated in Figures 7 and 8 for models representative of each substitution assumption. Here, the actual results of the models are displayed for the base case and the base case with tax and compared to the prediction that would be obtained from the three factor model with energy, capital, and labor. In Figure 7 the results are



* Models 1 and 2 have negligible substitution, by assumption.

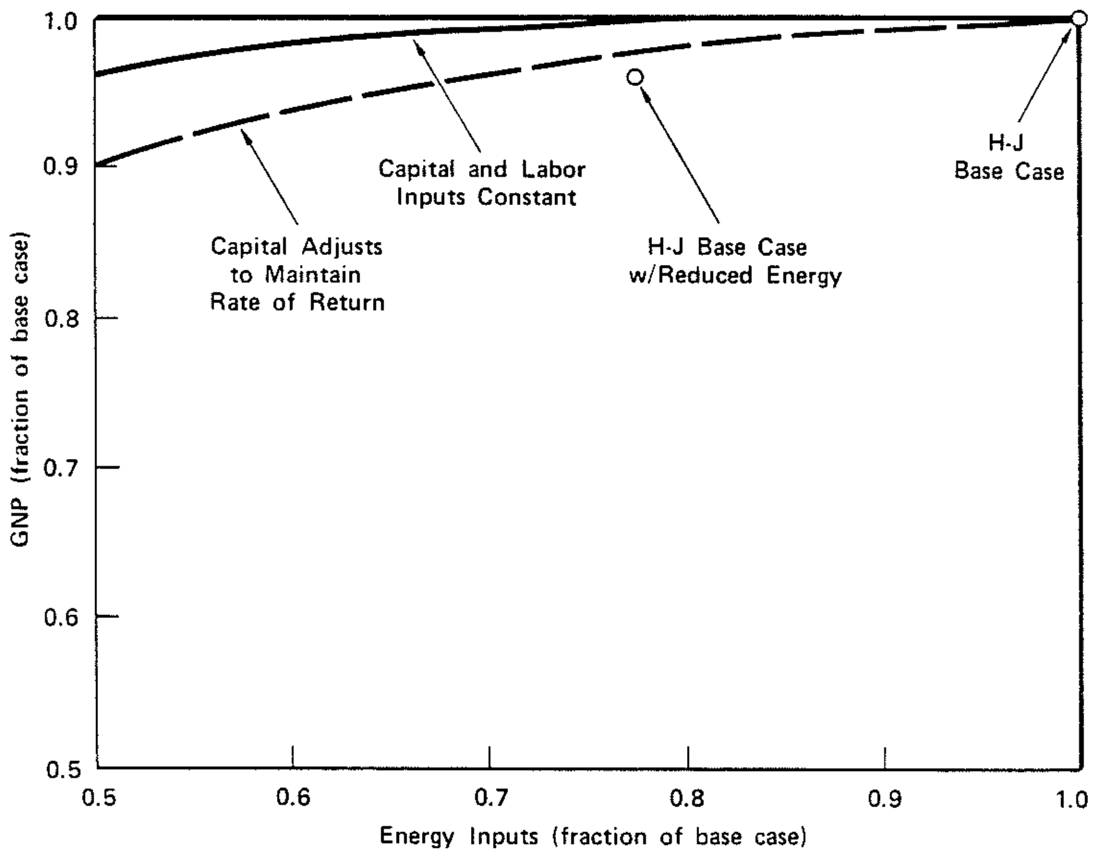
SOURCE: See Note 8.

Figure 6 Aggregate Elasticity of Substitution (Calculated Using the Outputs for the Base Case and the Base Case With Constraints)



SOURCE: See Note 8.

Figure 7 Comparison of PILOT Actual Results in the Year 2010 With the Simple Model of Substitution, Using PILOT's Implied Elasticity of Substitution (σ = 0.03)



SOURCE: See Note 8.

Figure 8 Comparison of Hudson-Jorgenson Actual Results in the Year 2000 With the Simple Model of Substitution, Using Hudson-Jorgenson's Implied Elasticity of Substitution ($\sigma = 0.49$)

shown for the PILOT model. Figure 8 depicts the same comparison for the Hudson-Jorgenson system. The simple analysis is not perfect, but it simulates the major portion of the aggregate effect found in the detailed models. It provides a guide for the proper use of the detailed systems by illustrating the central ideas embedded in the structure of the full models. The value share of the energy sector is a small component of the total economy. Small changes in energy input, therefore, have a small impact on aggregate output. For large changes in energy input, the estimate of the economic impact is significantly affected by the estimate of the elasticity of substitution.

The study has succeeded in identifying a central issue but has left many other issues unattended.

At this juncture it is useful to recall that our simple measure of economic impact, gross output, is not a complete description of all the effects of changing energy futures or the sole representation of the quality of life. Environmental effects play an important role in the evaluation of any energy option but, given our accounting system, they are excluded from direct consideration. Similarly, the international political implications of alternative energy conditions may be the dominant focus of concern. The economic impact may be overshadowed by national security priorities. Even within the realm of economic measures, important issues such as the distribution of income are submerged in the aggregate analysis. Evaluations of externalities or more detailed characterizations of the economy are essential in the assessment of specific energy options. Hence, the measurement of the aggregate elasticity of substitution does not complete the story. It is the essential first step. It is in the pursuit of complete analysis that the more detailed models establish their value. By exhibiting how individual industries respond to changing energy conditions, it becomes possible to estimate the environmental consequences of new energy options. By segregating demand by fuel type, the import and national security implications become more apparent. It is not the purpose here to examine the role of the detailed models in the study of these issues. Rather, the objective is to isolate the contribution of the models to the assessment of one important issue, the feedback from the energy sector to the economy. In exploiting the value of simplification, however, we should not neglect the contributions of the more detailed models. Where detail is crucial, a simple analysis does not suffice.

IMPLICATIONS OF THE MODEL COMPARISON

The economy has some flexibility but energy is important.

The implications of the comparison of models of the aggregate energy-economic interaction are significant. If there is no substitution, reductions in energy use produce corresponding reductions in economic activity. But if the higher estimates of the elasticity of energy demand are accepted, it follows that major changes in energy utilization can be achieved without corresponding changes in total economic activity. Even the recognition of the energy-capital effects embedded in the models does not alter this conclusion. However, we are not freed from difficult tradeoffs. The absolute impacts of the change in economic activity are significant. A given reduction in energy supplies may produce only a 1% reduction in GNP each year, but this can be a large loss in absolute value. It may justify a substantial research investment aimed at developing low cost technologies which can expand energy supply or improve the efficiency of energy utilization.

With some flexibility, energy sector models are still valid.

At a more technical level, the aggregate analysis can have important implications for energy modeling. If there is little energy substitution, the feedback effect is significant and energy models must account for this effect in representing the energy system. If the substitution potential is pronounced, the feedback effect is relatively small and separate energy sector models that hold aggregate economic activity constant can be justified. The changes in energy utilization and economic costs can be represented adequately by the first order effects contained in traditional demand curve analyses. This permits important modeling simplifications and expanded detail for the improved description of the operations within the energy system. Of course, the restriction to an energy sector model eliminates the capability of the full economy models to examine changes in the composition of economic activity.

NOTES

1 See, for example, the recent report of the Ford Foundation's Nuclear Energy Policy Study Group, Nuclear Power Issues and Choices, Ballinger Publishing Company, Cambridge, Mass., 1977.

2 Hogan, W. W., and Manne, A. S., "Energy-Economic Interactions: The Fable of the Elephant and the Rabbit ?", Working Paper EMF 1.3, Energy Modeling Forum, Stanford University, Stanford, Calif., July 1977. Found in Appendix B.

3 Sources for Figure 1. The GNP data in 1972 dollars are taken from the Economic Report of the President, 1977. The energy quantity data are from the Bureau of Mines. Primary energy prices are taken as the price of crude oil equivalent from Energy Perspectives, 1975, of the Department of Interior.

4 The elasticity of demand is defined here in terms of primary energy prices. This complicates the direct comparison of elasticity estimates from other studies due to definitional and aggregation problems. However, representative estimates for energy demand can be found in: M. L. Baughman and P. L. Joskow, "Energy Consumption and Fuel Choice by Residential and Commercial Consumers in the United States", MIT Energy Laboratory, May 20, 1975; Federal Energy Administration, National Energy Outlook, Appendix C, Feb. 1976; W. D. Nordhaus, "The Demand for Energy: An International Perspective", Cowles Foundation Discussion Paper 405, Yale University, New Haven, Conn., Sept. 1975.

5 The economic impacts of the simple model with a constant return on capital are developed for the full range of elasticity assumptions and energy input reductions in Appendix B. The complete dynamic general equilibrium analysis of the sophisticated models is required to analyze fully the capital-energy interactions. As an approximation, however, the ad hoc assumption of a constant rate of return can be viewed as appropriate for the comparison between two steady state balanced growth paths, where the rate of return is constant. This issue is discussed at greater length in Appendix C: W. W. Hogan, "Capital-Energy Complementarity in Aggregate Energy-Economic Analysis", Working Paper EMF 1.10, Energy Modeling Forum, Stanford University, Stanford, Calif., Sept. 1977. Found in Appendix C.

6 Hogan, W. W., and Parikh, S. C., "Comparison of Models of Energy and the Economy", Working Paper EMF 1.4, Energy Modeling Forum, Stanford University, Stanford, Calif., May 1977. Found in Appendix D.

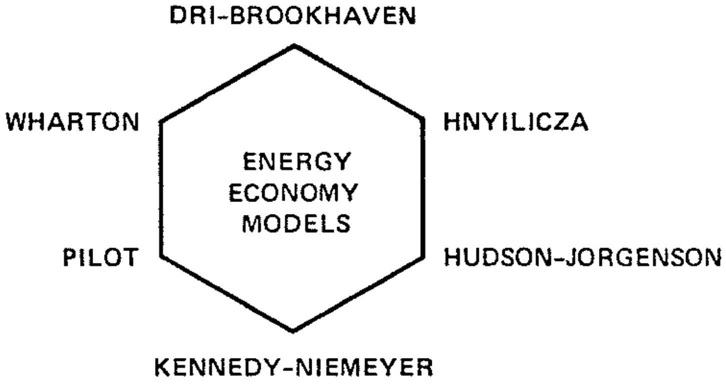
7 "Driving Variables, Scenario Definitions, and Individual Model Exceptions", Working Paper EMF 1.2, Energy Modeling Forum, Stanford University, Stanford, Calif., June 1977. Found in Appendix F.

8 Data from the results of the EMF model comparison, Appendix F.

Volume 2

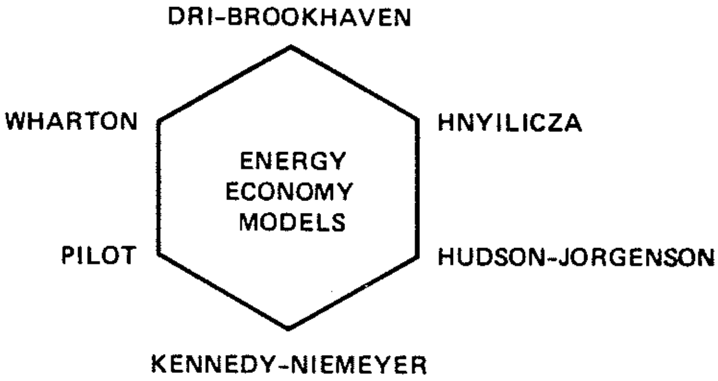
ENERGY AND THE ECONOMY

Appendices



Appendix A

INTRODUCTION TO EMF SUPPORTING DOCUMENTS



Appendix A

INTRODUCTION TO EMF SUPPORTING DOCUMENTS

SUMMER WORKSHOP

In recent years, several formal models of energy-economic systems have been in various stages of development and implementation. These models have the potential of providing a great deal of insight into many complex economic and environmental interactions. They could provide better answers to decision makers on a broad range of questions related to energy supply, demand, and distribution. Full realization of this potential, however, requires effective interaction between the decision maker and the model builder.

On July 21-23, 1976 a workshop was held at Stanford University under the auspices of the Electric Power Research Institute and the Stanford Institute for Energy Studies

- to explore interest in a Forum of decision makers and energy modelers operating through open discussion to make effective the use of models of energy-economic systems in the evaluation of energy options for the country,
- to explore ways to create and structure such a Forum panel, and
- to develop suggestions concerning the organizational structure for implementation of the Forum project.

It was hoped that the Energy Modeling Forum (EMF) approach could be developed as a way to promote the needed interaction to make the model methodologies more accessible for use and improvement. The proposed Forum's function, in general, would be:

- to use some of the major energy models to sharpen insights, improve understanding, and explore through open discussion the implications of selected energy decisions and scenarios;
- to disseminate analysis of the impacts of various energy options.
- to provide guidance for the improvement, linkage, and extension of energy models and to establish priorities for new modeling research;
- to identify critical elements of existing models and pinpoint the major strengths and weaknesses.

The provision of a strong user orientation is a central theme in the conceptualization and design of the Forum project. This focus on users was evident in the participation and structure of the three day workshop. Approximately 100 people attended the workshop, providing a broad representation of the model developers and users. Concrete suggestions for the structure and operation of the Forum project were presented, and information concerning the initiation of the Forum project was circulated through the energy model development and using communities. The details of the workshop discussions are reported in "Stanford-EPRI Workshop for Considering a Forum for the Analysis of Energy Options Through the Use of Models" [1].

The Stanford Institute for Energy Studies was selected by EPRI as the headquarters for the implementation of the Forum project, beginning with a six month experimental effort. Following the guidelines and suggestions of the summer workshop, this experimental study would test the viability of the Forum concept and the effectiveness of the organizational design.

THE MODELING RESOURCES GROUP

The methods and content of the first EMF study depend heavily on the work of the closely related Modeling Resources Group (MRG). The MRG is a subpart of the Committee on Nuclear and Alternative Energy Systems (CONAES), a large study directed by the National Research Council (NRC) to conduct a detailed analysis of the options available for the evolution of the U.S. energy system through the year 2010. The study is being conducted for ERDA and has a projected completion date in 1977.

The CONAES effort has been implemented through an extensive structure of panels and resource groups with participants from diverse backgrounds and institutions. A center of CONAES activity is the Synthesis panel which has responsibility for the integration of the tradeoff analysis inherent in the alternative energy scenarios. The MRG, chaired by Tjalling Koopmans, is one of the specialized groups reporting to the Synthesis panel. The broad purposes of the MRG are to identify and realize the contribution that formal energy models can play in the completion of the CONAES effort. Many members of the EMF working group have participated in the MRG activities, and we borrowed heavily from its innovations. An understanding of the history of the MRG provides a background for the formulation of the initial EMF study.

The mandate of the CONAES effort is substantially larger than the difficult but more focused tasks of the MRG. The CONAES study is designed to deal with a broad set of questions, exploiting all avenues of analysis and sources of information. The MRG provided input to the total effort while concentrating on the examination of the role of formal models in the analysis of future energy alternatives. The MRG consisted of representatives of several major energy modeling efforts and, bringing together modeling skills and several specific models, has undertaken two general activities. First, the members provided the characteristic advantages of formal modeling to the formulation of many key questions which the study must address. Second, the involvement of several models permitted the comparison of results across models to permit evaluation of the sensitivity of conclusions to changes in model structure.

The MRG proceeded in these activities through several steps. The general structures of the various models are explored through discussions. Lists of key variables and assumptions are established. The central values of these variables are researched or negotiated to produce a consistent set of inputs. Individual and collective variations in these input values are constructed to produce a set of scenarios designed to explore key features of the models. The scenarios are exercised by all models feasible and the results displayed and compared. The output comparisons focus on impact analysis for key policy changes, sensitivity analysis for change in realization of future states of the system, and the comparative explanation of results generated by different model structures. The Forum's methodological debt to the MRG is clear. The EMF adopted MRG procedures, energy sector assumptions, and selected a topic to complement the MRG focus on changes within the energy sector. Despite the addition of direct user involvement, the EMF remains the spiritual relative of the MRG.

FIRST EMF STUDY

The experimental period of the Energy Modeling Forum began in September 1976. For its first issue study, the EMF undertook the use of models to study the feedback from the energy sector to the economy. What is the nature and the strength of the link between the energy sector and the rest of the economy? An important topic in its own right, this subject is of particular interest because of the closely related work of the CONAES-MRG [2] or other recent studies, e.g., Ford-Mitre study [3]. The MRG studies examined detailed changes in models of the energy sector, but limited attention to consumer surplus approximations of the feedback magnitudes. The EMF models, by design, include the full economy and model the energy-economic linkages explicitly. The Ford-Mitre study uses an approach similar to that of the CONAES-MRG, but emphasizes the role of the "value-share" analysis. These issues are discussed in some detail in the various sections of this report. The Forum analysis concludes that a reduction in energy use need not produce a proportional reduction in economic output. This agrees with the main observation of these two related studies. The Forum results disagree, however, in the magnitude of the impact. The Forum results indicate that both the MRG and the Ford-Mitre assessments may underestimate the impact because of a lack of attention to the relationship between capital formation and energy availability. Properly, this detail is found only in the full models of energy and the economy.

Following the principles developed at the summer workshop, a group of interested model users and developers was organized to conduct the comparative study of several energy models in the examination of the link between energy and the economy. As in the MRG, tests of the models would be constructed and the working group would seek to explain the common results or the causes of any model differences. The EMF working group consisted of approximately 30 members from the energy modeling and analysis community (Table A-1). The first meeting was held on October 1-2, 1976 in Washington, D.C. At this meeting the working group familiarized itself with the selected models, agreed upon the assumptions for the driving variables, and defined six scenarios to be run by the modelers.

The working group met for the second time on December 10-11, 1976 in Palo Alto, California. At this meeting the first round of runs from the participating models was reviewed. The working group modified some of the assumptions and recommended a second round of scenario executions. The final results of the computer runs were to be reviewed by a subcommittee chaired by Gordon Corey of Commonwealth Edison. The Corey Subcommittee met on March 21, 1977 in Chicago. It reviewed the final results of the computer runs and developed the draft report of the study.

THE ORGANIZATION OF THE REPORT

During this study the participants in the working group developed a framework for comparing and interpreting the results of the models. This structure evolved in response to the attempts to explain apparent differences in the first

Table A-1

WORKING GROUP MEMBERS AND PARTICIPANTS

NAME	AFFILIATION
Gary B. Ackerman	Commonwealth Edison Company
David J. Behling, Jr.	Brookhaven National Laboratory
John C. Bukovski	Commonwealth Edison Company
Edward G. Cazalet	Decision Focus Inc.
Gordon R. Corey	Commonwealth Edison Company
Brian L. Crissey	National Research Council (CONAES)
George B. Dantzig	Dept. of Operations Research, Stanford University
William P. Drews	EXXON Corporation
Vijaya G. Duggal	Wharton Econometric Forecasting Associates
William F. Finan	Wharton Econometric Forecasting Associates
Dennis R. Fromholzer	Dept. of Engineering-Economic Systems, Stanford University †
Martin Greenberger	Electric Power Research Institute
Esteban Hnyilicza	Massachusetts Institute of Technology
Kenneth C. Hoffman	Brookhaven National Laboratory
William W. Hogan	Energy Modeling Forum
Edward A. Hudson	Data Resources Inc.
Lionel S. Johns	Office of Technology Assessment, U.S. Congress
Dale W. Jorgenson	Dept. of Economics, Harvard University
Michael Kennedy	Dept. of Economics, University of Texas *
Tjalling C. Koopmans	Cowles Foundation for Research in Economics, Yale University
Lester D. Lave	Dept. of Economics, Carnegie-Mellon University
Robert Litan	Cowles Foundation for Research in Economics, Yale University ††
Alan S. Manne	Dept. of Operations Research, Stanford University
William Marcuse	Brookhaven National Laboratory
E. Victor Niemeyer	Center for Energy Studies, University of Texas
David Nissen	Federal Energy Administration
William D. Nordhaus	Cowles Foundation for Research in Economics, Yale University ††
Shailendra C. Parikh	Energy Modeling Forum
Bruce A. Pasternack	Booz-Allen-Hamilton, Consultants
Milton Russell	Resources for the Future
Philip K. Verleger, Jr.	Council of Economic Advisers **
Jim Walker	California Energy Commission
John P. Weyant	Energy Center, Harvard University †††
Richard H. Williamson	Energy Research and Development Administration
David O. Wood	Massachusetts Institute of Technology

Current Affiliation

†	ERDA Conservation Planning and Policy
*	RAND Corporation
††	Council of Economic Advisers
**	U.S. Department of the Treasury
†††	Energy Modeling Forum

results of the models. The major conclusions of the study formed in conjunction with the elaboration of this comparative structure. In part, this framework centers on the simplification of the basic principles embedded in the models to highlight the key assumptions dominating the energy-economy interactions. The chief responsibility of the working group here was to isolate these key elements and make them accessible to a wide audience of potential model users. An example of this type of result is the illustration of the central role of substitution assumptions in determining the link between energy and the economy.

The explication of key assumptions is an expected output of the EMF studies. Generally these results are known to the modelers and their discovery is no surprise. An unexpected part of the model comparison, however, was the investigation of certain model characteristics known only to a few of the modelers at the start of the study. The link between capital and energy in determining the long run impact of energy scarcity can be cited in this regard. An apparent benefit of this first study is the stimulation of new model development efforts dealing with some fundamental technical issues, but these more technical matters are not dealt with at length in this report except as they influence the immediate comparison of the models. These are left to the individual modelers, some of whom have undertaken major development efforts, stimulated to a degree by the interaction in the EMF study.

The EMF report concentrates on the first type of result, the illustration and exposition of the underlying structure of the models. The purpose is to improve the understanding of these models and to make them more accessible to potential users. The presentation of these results is organized in two main segments. A general summary of the full study is presented in Volume 1. This summary is intended for wide circulation and, therefore, is written with an effort to minimize the technical details and specialized jargon. Volume 1 captures the most important themes in the model comparisons with an emphasis on the positive contributions of the models. The detailed model results and analytical support for this summary are organized in several appendices of Volume 2 of the report, beginning with this introduction and overview. Some of these appendices are usable as separate papers. The effort to minimize the technical detail is continued.

Appendix B (EMF 1.3)

With energy treated as an economic good, the basic structure of the models starts with the small value share of energy in the total economy, the potential for the substitution of other factors of production, and the possible impacts of the link between capital and energy. The importance of these ideas can be illustrated without the detail necessary for a full scale modeling system. The paper, "Energy-Economic Interactions: The Fable of the Elephant and the Rabbit ?", by Hogan and Manne [4] presents this simplified analysis. This framework establishes the structure for the comparison of the results from the detailed models as presented in Volume 1.

Appendix C (EMF 1.10)

The link between capital and energy is an important component of the full feedback effect of energy on the economy. The nature of this link is a subject of debate with conflicting evidence available in different studies. This issue is discussed in further detail in the paper, "Capital-Energy Complementarity in Aggregate Energy-Economic Analysis", by Hogan [5]. The proposed resolution of the debate lends support to the simplified analysis presented in Volume 1 of this report.

Appendix D (EMF 1.4)

The models included in the EMF study are diverse in terms of structure, intent, level of aggregation, and key problem assumptions. Upon close inspection, however, all the models have certain common features. The paper, "Comparison of Models of Energy and the Economy", by Hogan and Parikh [6] develops a straightforward taxonomy for these models by exploiting the common accounting structure. This includes identification of key model characteristics relevant to the EMF study. This should provide an introduction for potential users of these models.

Appendix E (EMF 1.7)

The purpose of the Forum studies is to make models more useful. The strong emphasis is on the positive, to describe the contributions of the models and the key information needed to use them successfully. But the models are far from perfect. In fact, as with all simplifications (including implicit mental models), there is a long list of problems and limitations. In the paper, "Strengths and Limitations of the Models: The EMF Process from a User's Perspective", [7] Walker discusses some of the more important model limitations, concentrating on characteristics which might be imputed to these models but which they do not possess. In addition, Jim Walker summarizes the value and operation of the EMF study from the perspective of a participating model user.

Appendix F (EMF 1.8) [8]

The conduct of the EMF model tests requires the specification of a large array of input assumptions and the interpretation of an equally large array of output information. These data, the corresponding test scenarios, the model deviations from central assumptions, the selected graphs with commentary, and the full listings of the model results are presented in this lengthy technical appendix.

Appendix G (EMF 1.9) [9]

The documentation of the individual models exists with a high variance on completeness and usability. The working group assembled short summary documentation from each participating modeler. This appendix includes these short model summaries. Lengthier documentation is available in a variety of forms from the EMF, the participating modelers, or publications in the open literature.

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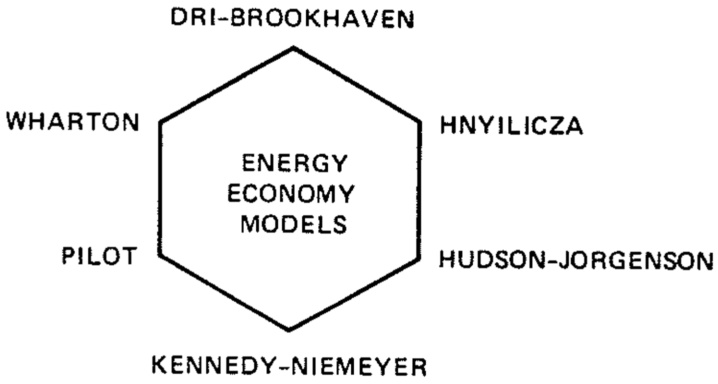
[8] "Scenario Implementations for the Participating EMF Models", Working Paper EMF 1.8, Energy Modeling Forum, Stanford University, Stanford, Calif., May 1977.

[9] "Abbreviated Model Documentation", Working Paper EMF 1.9, Energy Modeling Forum, Stanford University, Stanford, Calif., May 1977.

Appendix B

ENERGY-ECONOMY INTERACTIONS: THE FABLE OF THE ELEPHANT AND THE RABBIT ?

This appendix develops a simple framework for representing the interactions between the energy sector and the economy. The results of the detailed EMF models find their primary comparison in this report at the level of the model presented in this appendix.



ENERGY-ECONOMY INTERACTIONS:
THE FABLE OF THE ELEPHANT AND THE RABBIT ?

by

William W. Hogan and Alan S. Manne

Working Paper

EMF 1.3

July 18, 1977

Energy Modeling Forum
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ABSTRACT

This paper presents an aggregate analysis of energy-GNP interactions. The results underscore the importance of two parameters: the relative size of the energy sector, and the elasticity of substitution. These appear to be the dominant factors in conservation policy and in energy demand model design.

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Appendix B

ENERGY-ECONOMY INTERACTIONS: THE FABLE OF THE ELEPHANT AND THE RABBIT ?

INTRODUCTION

In most energy policy studies, the energy sector is viewed in isolation from the remainder of the economy, and the analysis is performed without consideration of the broader impacts. Typically, the GNP and other macroeconomic indices are taken as given--as though they were unaffected by the energy sector. This is not fully satisfactory, for there could be two-way interdependence with the remainder of the economy.

As a rough measure of the cost (or benefit) of a given energy policy, it often is sufficient to calculate the impact upon the aggregate consumption or the GNP. The dollar magnitude of this impact may be significant and highly relevant to energy policy. Nonetheless, even a large absolute amount may constitute only a small fraction of the GNP. It is in this sense that there may be virtually one-way linkage--that the GNP growth rate may affect the energy sector but not vice versa. With one-way linkage, there would be no need to couple the energy sector with an economywide analysis. Approximate estimates of economic impacts would be adequate for energy policy evaluations. If it turns out, however, that two-way linkages are significant, we cannot treat the energy sector in isolation but must consider the full interdependence effects.

Before undertaking a complex analysis of the interdependence effects, it would appear useful to make a rough assessment of their magnitude. That is the purpose of this paper. We present a simple model for organizing the central concepts and the parameters that might underlie a more realistic study. This aggregative model provides insights and indicates the possible range of energy policy impacts upon the economy as a whole.

THE ELEPHANT AND THE RABBIT ?

For simplicity, we represent the economy in terms of just two inputs--energy and all other items. Note that energy is only a small component of the U.S. economy. As of 1970, the value of primary energy inputs did not exceed 4% of the GNP. At 1970 or even current prices, this is something like an elephant-rabbit stew. If such a recipe contains just one rabbit (the energy sector) and one elephant (the rest of the economy), won't it still taste very much like elephant stew?

If prices had not risen after 1970, it is likely that energy demands would have grown at about the same rate as the GNP. The 4% ratio then would continue into the future. But what if energy costs double, and there is sufficient time for the economy to adapt to this change? A naive estimate of the impact may be obtained by assuming a constant input mix. On this basis, an additional 4% of the GNP must be allocated to cover the costs of energy. Other input-mix options are in fact available, and some would lead to lower costs. Thus, the first doubling of energy costs would produce, at most, a 4% loss in GNP.

Reductions in the physical availability of energy also can be interpreted in terms of higher costs. However, for questions phrased in terms of the physical availability rather than dollar costs, an alternative application of the value share is useful. The elephant-rabbit analogy still is applicable, if there is sufficient time for the economy to respond smoothly to changes in the availability of energy relative to other inputs. The value share of the energy sector determines the incremental effect upon the GNP. If the 4% value share remained constant, this would mean that a 10% reduction in energy inputs would produce only a 0.4% drop in total output. Thus, for small changes in energy availability, there need not be a proportional impact upon the economy as a whole.

For large reductions in the availability of energy, the value share need not remain constant. If the value share rises, the GNP effects may become more pronounced. To evaluate large changes, we must proceed beyond the metaphor of the elephant and the rabbit.

SUBSTITUTION

The processes for future production and utilization of energy are not fixed immutably. Insulation, engine efficiency improvements, and "input juggling" in production processes all can alter the energy requirements for a fixed level of output.

Such substitution modifies the economic impacts of changes in the energy system. This flexibility in energy utilization is the next essential element, after the value share of energy, in measuring the magnitude of the energy-economic feedback. It also characterizes the key difference among many energy models. In economists' jargon, different assessments of this flexibility of energy utilization can be phrased as a disagreement over the numerical value of the "elasticity of substitution". This is a measure of the ease or difficulty of replacing energy with other inputs.

The discussion is simplified here by restricting attention to the long run, when energy equipment and processes can be changed substantially. Not that the short run is unimportant, but the character of the problem is different. A sudden shock may create far more serious problems than the gradual long-run pressures of resource exhaustion. Here we focus only on these long-run adjustments.

The elasticity of substitution concept is illustrated in Figure B-1. The point identified as "current input mix" represents one possible combination of the inputs of energy and other factors (capital and labor) used to provide a given level of total output. The lines drawn through this point indicate alternative combinations of inputs that could be used to produce the same level of output. These constant output curves summarize the potential for substitution between energy and other inputs. Except for the explicit assumption that energy and other inputs are substitutes (i.e., that the slopes of these curves are negative), the general shape of these curves might be quite varied. Three alternatives are shown in Figure B-1--with elasticities of substitution equal to zero, one, and infinity.

If the energy-GNP ratio were an immutable constant, this would imply a <u>zero</u> elasticity of substitution. It would mean that total output could not be increased without increases in both energy and nonenergy inputs. This fixed proportions assumption flies in the face of common sense. It is reminiscent of the theories that led the U.S. and its allies to attempt to destroy the German ball bearing industry during World War II, and thereby to knock out the entire German economy.

At the opposite extreme, if all inputs to the economy were completely fungible, there would be an <u>infinite</u> elasticity of substitution. This also flies in the face of common sense. It would mean that machinery could run without energy, or that energy would be useful without machines.

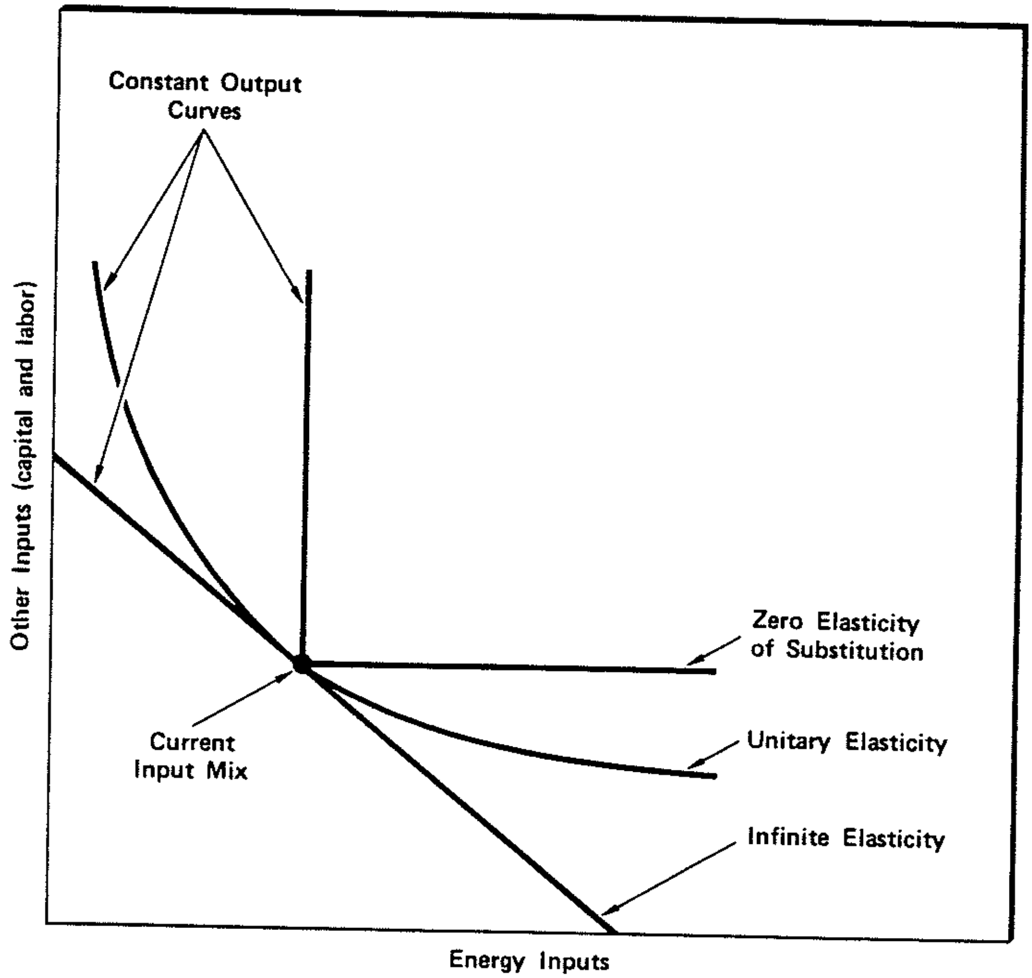

Figure B-1 The Elasticity of Substitution Concept

Still another hypothesis is that the elasticity of substitution is unity. This would imply that as the relative price of energy increased, the optimal value share of energy inputs would still remain constant at, say, 4% of GNP.

The elasticity of substitution need not be either zero or unity or infinity. If we restrict ourselves to a constant elasticity of substitution, we cannot construct a simple model of energy-economy linkages. In examining the implications of this model, however, it is not necessary to rely on altogether arbitrary judgments as to the appropriate elasticity. For this aggregate model, the numerical values of the long run price elasticity of demand and of the long run elasticity of substitution are virtually identical. Therefore, many econometric and engineering studies of the price elasticity of energy demand can be applied directly to the measurement of the elasticity of substitution. Unfortunately, a variety of defects can be found in each empirical study. Unlike the value share of the energy sector, no definitive estimate of the elasticity of demand/substitution is available. The weight of the evidence would suggest that the elasticity lies between 0.2 and 0.6.[†] In presenting the economic impacts of alternate energy availabilities, we encompass this range of elasticities--partly because of the empirical evidence and partly because the results do not vary significantly for elasticities that are either much higher or much lower.

For the present purposes, it is reasonable to assume that energy demand would grow at a rate close to that of the total economy if relative energy prices were to remain constant. A 3% per year growth over 1970 would imply a GNP in 2010 of approximately $4400 billion (1975 dollars) and a total primary energy input of 220 quads. Suppose that for reasons of resource conservation, environmental protection, or national security, there is a need for reduced energy consumption. Suppose further that there is no reduction in the economic inputs other than energy. One way to achieve a reduction in energy consumption would be through an energy conservation tax with the tax revenues fully redistributed. Other policy measures (e.g., auto efficiency standards) also could achieve much the same goal, but for illustrative purposes we shall simply describe all of these as a Btu tax.

[†] The elasticity of demand is defined here in terms of primary energy prices. This complicates the direct comparison of elasticity estimates from other studies due to definitional and aggregation problems. However, representative estimates for energy demand can be found in [1, 2, 3].

This tax represents the incremental value of energy at the various consumption levels. Under these assumptions, the feedback issue can be posed through two questions:

- What is the size of the necessary Btu conservation tax?
- What is the resulting impact on GNP?

For alternative values of the elasticity of substitution, the answers to these questions are illustrated in Figure B-2. This graph depicts the GNP that would result at various levels of energy input, ranging from the reference value of 220 quads down to 70 quads, if the inputs of capital and labor are held constant, and if energy costs remain constant. The results are shown for elasticities of substitution between 0.1 and 0.7. The slope at each point indicates the "Btu tax" needed to achieve the specified level of energy consumption. Thus, if the elasticity of substitution is 0.3, a tax of $\$5.76/10^6$ Btu would be needed to reduce energy consumption from 220 quads to 110 quads. The resulting GNP would be reduced from $4400 billion to $4213 billion (4.3%). For convenience, the same information is repeated in tabular form in Table B-1.

According to this simple model, the long run elasticity can have a startling effect. A 50% reduction in energy utilization would produce a 28% reduction in GNP if the elasticity is 0.1, but only a 1% reduction in GNP if the elasticity is 0.7. The taxes required to achieve these reductions display a corresponding variation. Most existing estimates of the price elasticity of demand for primary energy would fall within the range of 0.2 to 0.6. The issue certainly has not been resolved, and there is some evidence for both higher and lower values. It is essential, therefore, that any improved analysis of the energy-economy link provide a careful specification of the elasticity of demand/substitution. Most modeling efforts can be characterized in terms of their treatment of this important concept.

EXTENSIONS OF THE ANALYSIS

The estimate of economic impact is sensitive to simplifying assumptions, one of the most questionable being that changes in energy availability do not affect the pattern of investment and the long run inputs of capital services. The effect of this assumption can be illustrated by extending the initial framework to include three inputs to the economy: energy, capital, and labor. Instead now of holding capital and labor constant as energy changes, let capital adjust to maintain its

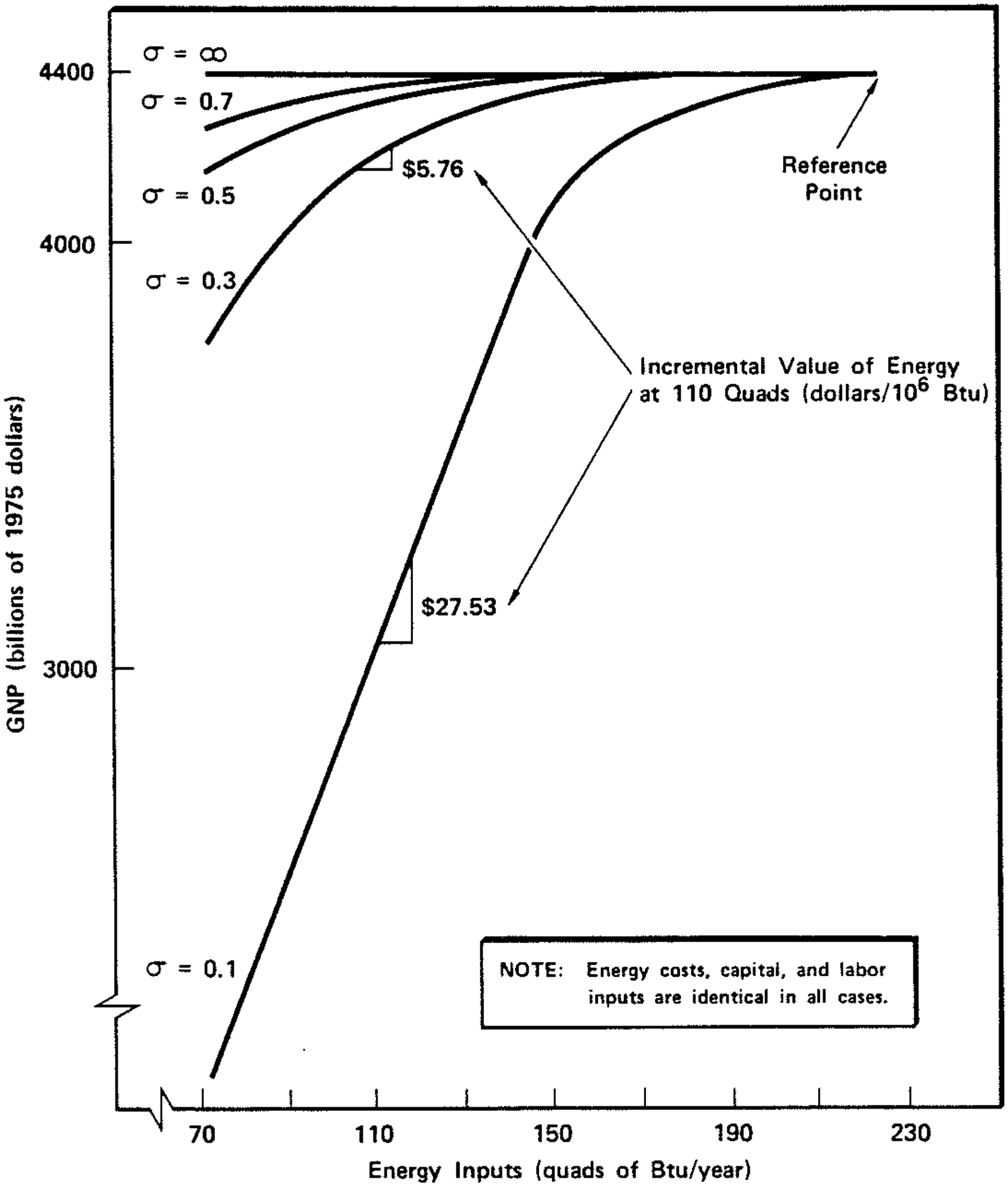

Figure B-2 Economic Impacts of Energy Reductions in the Year 2010 for Various Elasticities of Substitution (σ)

Table B-1

ALTERNATIVE ESTIMATES OF ECONOMIC IMPACT IN THE YEAR 2010

(with constant energy costs and constant capital and labor inputs)

E = quads of energy in 2010	ELASTICITY OF DEMAND/SUBSTITUTION				
	0.1	0.2	0.3	0.5	0.7
	Percent Reduction in GNP				
220	0	0	0	0	0
190	0.6	0.3	0.2	0.1	0.1
160	4.5	1.3	0.8	0.4	0.3
110	27.7	9.2	4.3	1.9	1.2
70	53.8	30.8	14.3	5.2	3.0
	Incremental Value of Energy ($\$/10^6$ Btu)				
220	0	0	0	0	0
190	2.40	.80	.48	.26	.18
160	10.37	2.69	1.38	.67	.44
110	27.53	13.69	5.76	2.17	1.26
70	29.05	34.52	19.24	5.94	2.99

Note: Developed using base case assumptions and approximations discussed in the Appendix. Throughout, it is assumed that if 220 quads of energy were available, the GNP would be \$4400 billions in 2010 (when expressed at 1975 prices). The cost of energy is in all cases the 1970 price: \$.80 per million Btu. The incremental value represents the excess over this amount.

rate of return.[†] The impact of this change in assumption is displayed in Figure B-3 for an elasticity of 0.3. At an energy input reduction of 50%, the adjustment of capital from a constant input to a constant rate of return increases the economic impact. Instead of 4%, the impact now becomes 11%. The energy tax needed to achieve this reduction in energy use is $4.33/10^6$ Btu. But the potential for substitution still preserves the basic qualitative results. Reductions in energy input need not produce proportional reductions in total economic output. The economic impact of energy conservation is quite sensitive to the assumptions--either explicit or implicit--on the elasticity of substitution. (See Table B-2.)

Other objections can be raised against this analysis. First, the aggregation may disguise distinctly different behavior in individual sectors. The specific processes for energy substitution are varied and intricate. The morass of detail may be approached gradually by expanding the simple model for improved description of the elasticities through the separate analysis of more representative groupings. Second, the aggregate substitution parameter does not provide an engineering description of the new processes and the technologies that must be adopted. A more disaggregated analysis is needed in order to provide the detail to lend credibility to the simple analysis. A large part of the motivation for the construction of more sophisticated models can be viewed as the need for overcoming these difficulties by improving the aggregate estimate of the elasticity of demand/substitution or by providing a demonstration of energy utilization flexibility at a verifiable level of detail.

POLICY AND ANALYTIC IMPLICATIONS

The implications of substitution are significant for the energy-economic interface. If there is no substitution, reductions in energy use produce corresponding reductions in economic activity. But if the higher estimates of the elasticity of energy demand are accepted, it follows that major changes in energy utilization can be achieved without corresponding changes in total economic activity. Even in the latter case, we are not freed from difficult energy policy tradeoffs. The

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[†] Examining the relationship between capital and energy leads to the debate about complementarity versus substitution and the proper measurement of the Allen partial elasticities of substitution. Because of our aggregation to the level of the total economy and our range of elasticities, the resolution of this debate does not affect our qualitative results about the impacts of reduced energy or capital. The conflicting empirical arguments are found in [4, 5, 6]. This debate and the relevance of the assumption of a constant return on capital are discussed at length in [7].

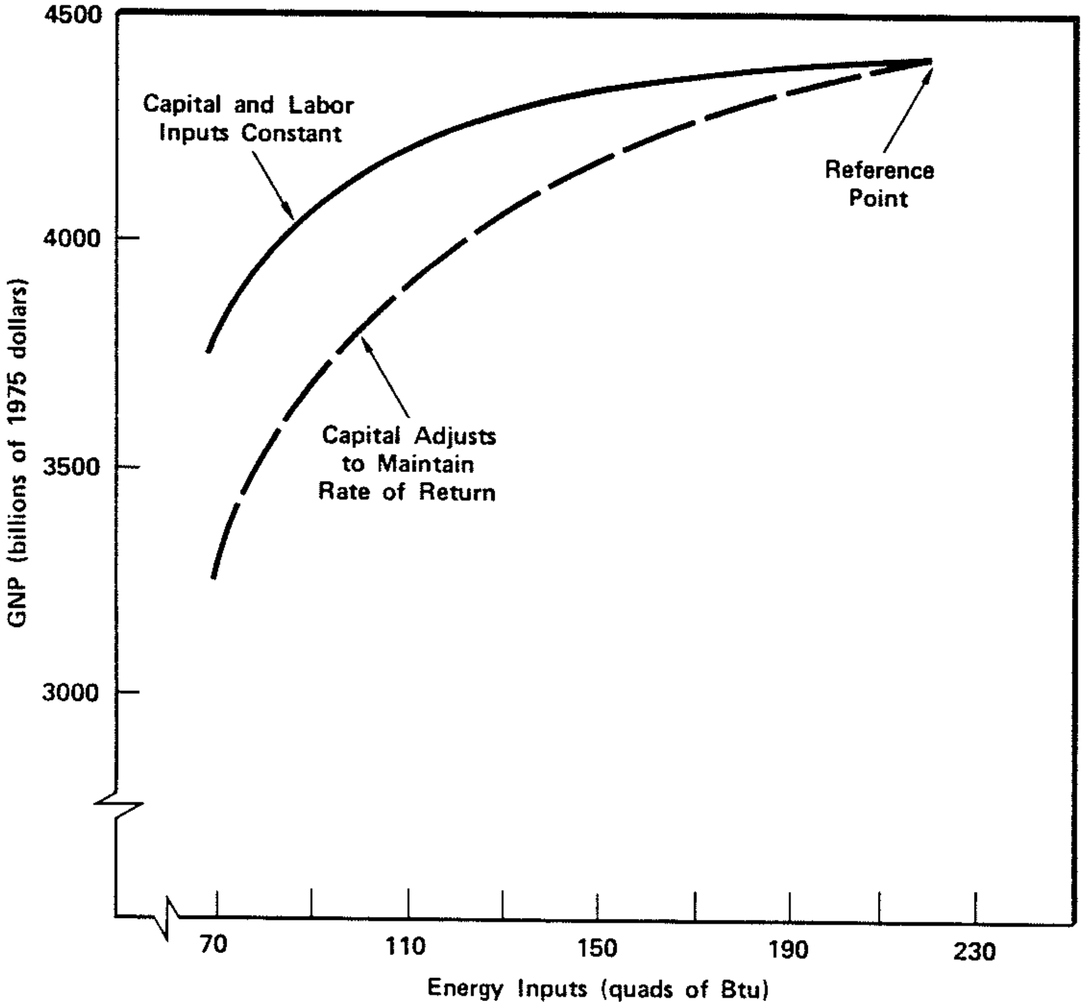

Figure B-3 Economic Impact of Energy Scarcity in the Year 2010 for Alternate Capital Assumptions (Elasticity of Substitution $\sigma = 0.3$)

Table B-2

ALTERNATIVE ESTIMATES OF ECONOMIC IMPACT IN THE YEAR 2010

(with constant energy costs, constant labor inputs,
and a constant rate of return on capital)

E = quads of energy in 2010	ELASTICITY OF DEMAND/SUBSTITUTION				
	0.1	0.2	0.3	0.5	0.7
	Percent Reduction in GNP				
220	0	0	0	0	0
190	4.0	2.0	1.4	1.0	1.0
160	12.0	5.7	3.5	2.1	1.8
110	33.4	19.2	11.3	5.5	3.9
70	55.6	39.9	25.8	11.7	7.2
	Incremental Value of Energy ($/$10^6$ Btu)				
220	0	0	0	0	0
190	1.41	.67	.42	.24	.17
160	4.26	2.00	1.19	.62	.41
110	11.94	7.41	4.32	1.95	1.18
70	19.63	16.79	11.69	5.06	2.76

Note: Developed using base case assumptions and approximations discussed in the Appendix. Throughout, it is assumed that if 220 quads of energy were available, the GNP would be $4400 billions in 2010 (when expressed at 1975 prices). The cost of energy is in all cases the 1970 price: $.80 per million Btu. The incremental value represents the <u>excess</u> over this amount.

absolute impacts of the change in GNP may be significant. A small proportion of a large number still remains a large number. A given reduction in energy supplies may produce only a 1% reduction in GNP each year, but this can be a large loss in dollar terms. If the economy is growing at 3% in real terms, and we discount future consumption at 6%, a 1% reduction in annual GNP corresponds to a present value of nearly half a trillion dollars. Such a figure would justify a substantial research investment aimed at developing low cost technologies which expand energy supply or improve the efficiency of energy utilization.

At a more technical level, the implications for energy modeling may be more conclusive. If there is little energy substitution, the feedback effect is significant, and energy models must account for this effect in representing the energy system. However, if the substitution effects are significant, the feedback effect on the evaluation of the energy system is relatively small. In this case, the energy sector may be analyzed by itself. The changes in energy utilization and economic costs can be represented adequately by the first order effects contained in traditional microeconomic demand curve analyses. This permits important modeling simplifications and expanded detail for the improved description of the energy system.

SUMMARY

A simple aggregative model can illustrate some key concepts in determining the economic impacts of energy policies. The small relative size of the energy sector motivates the metaphor of the elephant and the rabbit. It indicates that small changes in energy availability do not produce proportional changes in economic activity. The elasticity of substitution determines the economic impacts for large changes in energy availability. A low elasticity implies significant interactions. Higher elasticities may yield important economic impacts, but these may be represented adequately in an isolated analysis of the energy sector.

APPENDIX

INTRODUCTION

The metaphor of the elephant and the rabbit applies to an aggregate view of the economy with a single output and two inputs. If this approximation is accepted and if certain accounting conventions are adopted, it is straightforward to manipulate static comparisons of this model. This appendix records the aggregation and accounting conventions, summarizes the development of the two-factor model, and develops its application. An extension is presented to illustrate the possible relationship between energy and capital inputs.

ACCOUNTING CONVENTIONS

A basic accounting structure is needed to proceed toward a quantitative analysis of energy-economic interactions. To focus on the essentials, we distinguish initially between only two types of economic inputs--energy, denoted by E with price P_E, and all other inputs, denoted by R with price P_R. Here, the symbol R denotes the aggregate economic value of inputs such as capital and labor, assuming that their relative prices do not change significantly. Later we examine one disaggregation of R into its capital and labor constituents.

With this notation, the economic transactions of Table B-3 summarize the accounting conventions for the production and use of energy and nonenergy goods. Energy is treated as an intermediate product contributing to the ultimate production of goods and services for final demand. This might be the case, for example, if the consumer is viewed as demanding transportation services rather than gasoline. Attention is focused here on the gross output of the nonenergy sector, denoted as Y. This output is measured in the same units as GNP. As the only consumer good, it is assumed throughout to have a price of 1. From the standard identity relating the value of inputs and outputs, we have

$$Y = P_E E + P_R R \qquad (1)$$

and also,

Table B-3

INTERINDUSTRY TRANSACTION FLOWS

TO / FROM	ENERGY	NONENERGY	FINAL DEMAND
ENERGY	0	$P_E E$	0
NONENERGY	$P_E E$	0	GNP
PRIMARY FACTORS	0	$P_R R$	

$$Y = P_E E + GNP \quad . \tag{2}$$

The heart of the model is the assumed aggregate production function relating gross output (Y) to the inputs of energy (E) and all other factors (R) :

$$Y = F(E,R) \quad . \tag{3}$$

It is assumed that F is a positive, differentiable, concave function exhibiting constant returns to scale. Each of these assumptions is supported by plausible economic intuition.

EFFICIENT SOLUTIONS AND THE VALUE SHARE

If producers are making efficient choices, they are, in effect, solving the problem:

$$\text{Max} \quad F(E,R) - P_E E - P_R R \quad . \tag{4}$$

Then for an economically efficient solution, the price of energy must equal its marginal productivity:

$$\frac{\delta F}{\delta E} = P_E \quad . \tag{5}$$

The importance of the relative size of the energy sector can be demonstrated without any additional information about the production function. From (5), it follows that

$$\frac{\delta F}{\delta E} \cdot \frac{E}{Y} = \frac{P_E E}{Y} \quad . \tag{6}$$

The left hand side of (6) is the elasticity of output as the input of E varies, assuming that R is held constant. The right hand side of (6) is the value share of the energy input as a proportion of total output. If $P_E E/Y = s$, then a 1% change in the energy input produces an s% change in gross output. If we assume that the value share, s , remains approximately constant over a wide range of E , then

$$\frac{Y}{Y_0} \approx \left(\frac{E}{E_0}\right)^s \quad . \tag{7}$$

Under these conditions, with the 1970 level of $s = .04$, a 50% reduction in E would lead to only a 2.7% reduction in Y . Even with $s = 0.1$, a 50% reduction in E would produce only a 6.6% reduction in Y .

This observation is the motivation for the fable of the elephant and the rabbit. This analogy would be persuasive if the energy value share did indeed remain constant. Even major changes in energy inputs then could be accommodated over the long run with a small effect on output. But constancy of s is a strong assumption, and it depends crucially upon the degree of potential substitution between energy and other inputs. If the substitution possibilities are quite limited, then one effect of a change in energy availability is to increase the energy value share. There then could be large impacts upon the economy.

The importance of the elasticity of substitution is a main theme of this paper. (Recall Figure B-2.) The next section of this appendix develops a two-factor model on the basis of different elasticities of substitution, but drops the assumption of a constant value share, s .

ELASTICITY OF SUBSTITUTION

The elasticity of substitution provides a dimensionless index of the relationship between the relative use of the two inputs and their relative marginal productivities. Formally, the elasticity of substitution is defined as:

$$\sigma = - \frac{\delta \ln (E/R)}{\delta \ln\left(\frac{\delta F/\delta E}{\delta F/\delta R}\right)} \quad . \tag{8}$$

A constant elasticity of substitution implies that a given percentage change in the ratio of the two inputs (holding output constant) produces a constant but opposite percentage change in their marginal rate of substitution. This somewhat awkward definition provides the minimal approximation of the substitution potential in any production function with adequate flexibility for analysis of the feedback issue. Excluding three special cases (that is, for $\sigma \neq 0, 1, \infty$), (3) now becomes

$$Y^{\frac{\sigma-1}{\sigma}} = aE^{\frac{\sigma-1}{\sigma}} + bR^{\frac{\sigma-1}{\sigma}} \tag{9}$$

where a and b are two constants.

For given prices, the input mix must satisfy the first-order optimality condition in (5) above,

X

$$\frac{\delta \overset{F}{\cancel{E}}}{\delta E} = a\left(\frac{Y}{E}\right)^{\frac{1}{\sigma}} = p_E \quad . \tag{10}$$

At constant prices, equation (10) implies that E/Y will be constant (approximately a constant energy-GNP ratio). For changing prices, however, this ratio will change.

For the present discussion, observe that (10) may be inverted to relate energy use to output and prices,

$$E = Ya^{\sigma}\left(P_E\right)^{-\sigma} \quad . \tag{11}$$

Note that the marginal productivity function (11) is the approximate form of many empirical studies of energy demand as a function of output and prices. Now, if Y is <u>approximately</u> independent of E, equation (11) implies that the price elasticity of demand for energy remains nearly constant and is virtually identical to the elasticity of substitution. Hence, the more familiar concept of the aggregate price elasticity of energy demand can be used to estimate σ.

The production function in (9) and the demand function in (11) are the center of the aggregate analysis. The importance of the σ parameter is indicated when we interpret (11) in the context of value shares. Analogous to the discussion of the previous section, equation (6) can be restated as,

$$s = \frac{P_E E}{Y} = a^{\sigma}\left(P_E\right)^{1-\sigma} \quad . \tag{12}$$

This means that s (the value share of energy) is a function of the real price of energy. If the elasticity of substitution or demand is 1, the value share is constant. However, if σ is less than 1, an increasing price of energy implies an increasing value share associated with a reduced availability of energy. At small values of σ, s increases rapidly, and energy reductions produce large reductions in GNP.

The price elasticity of the demand for energy in equation (11) no longer is constant once we account for the adjustments in output induced by the price changes. At any point, the exact elasticity is $-\sigma/(1-s)$. The impact of rising shares is to reduce demand further through the feedback.

PRODUCTION FUNCTION ANALYSIS

The production function analysis utilizes the constant elasticity production function and the associated demand curve. Figure B-4 illustrates the relationship between Y, GNP, and P_E. Given σ and base estimates of Y_0, E_0, R_0, and $P_{E,0}$,

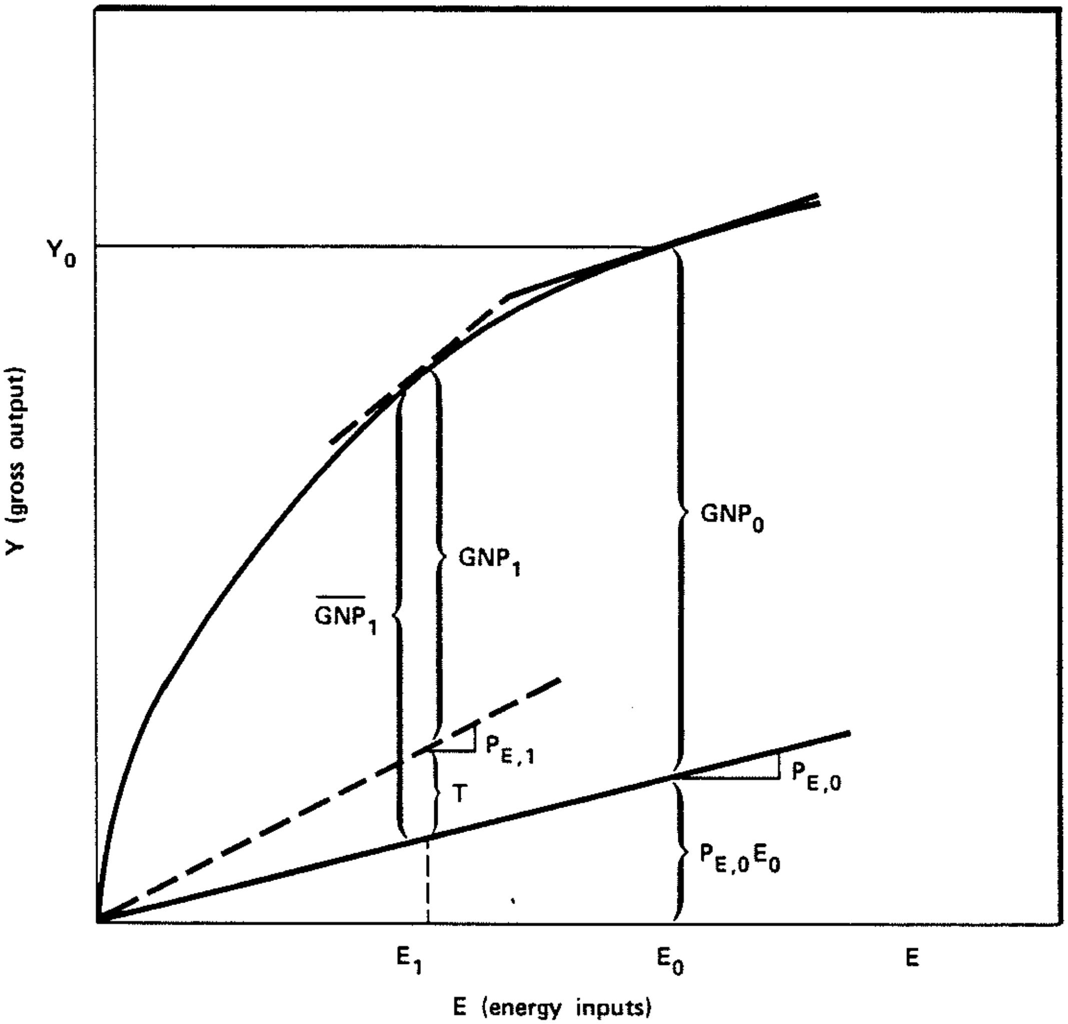

Figure B-4 Output as a Function of Energy Input equations (9) and (11) determine the parameters a and b. Variations in E then determine variations in P_E, Y, and GNP with R_0 held constant. In moving from E_0 to E_1, there is an increase in P_E, a decrease in Y, and a larger decrease in GNP.

If the increase in energy price is a real resource cost (e.g., all energy is imported from OPEC), then the increase in price and decrease in output reduces the GNP to GNP_1. However, if the price increase and reduced demand are achieved through a tax, the tax revenue is T. If this revenue is returned to consumers and transferred to nonenergy uses, the new GNP or real income level is $\overline{GNP}_1 = GNP_1 + T$. The magnitude of each of these changes depends on the curvature of the function as determined by σ, the elasticity of substitution.

To illustrate these calculations, recall from (11) that

$$E_0 = Y_0 a^{\sigma}\left(P_{E,0}\right)^{-\sigma} \quad . \tag{13}$$

Therefore,

$$a = \left(\frac{E_0}{Y_0}\right)^{1/\sigma} \cdot P_{E,0} \quad . \tag{14}$$

From the assumption of constant returns to scale and the accounting conventions, we know that

$$Y = P_R R + P_E E \tag{15}$$

and $P_{R,0}R_0 = GNP_0$. By appropriate choice of units, we can define $R_0 = 1$. Since R_0 must satisfy optimality condition corresponding to (11), it follows that

$$R_0 = Y_0 b^{\sigma}\left(P_{R,0}\right)^{-\sigma} \quad , \tag{16}$$

or

$$b = GNP_0\left(Y_0\right)^{-1/\sigma} \quad . \tag{17}$$

Given a and b, (9) determines Y for any E_1 with $R_0 = 1$. Equation (11) determines the associated price $P_{E,1}$, which then yields GNP_1 and $\overline{GNP}_1$ as in Figure B-4.

In Table B-4, prices and GNP values are presented for different values of energy demand in the year 2010. These results are obtained by assuming that the equilibrium E and GNP would have grown at a 3% annual rate from 1970 to 2010, if energy prices had remained at their 1970 level of $.80 per million Btu. (This represents the 1970 U.S. wellhead price of crude oil, expressed in terms of the 1975 general price level.)

Table B-4 shows the importance of the elasticity of substitution. If this parameter is as high as 0.5, there is substantial decoupling of energy and the GNP, even at energy consumption levels as low as 110 quads in the year 2010. But if the elasticity of substitution is 0.1, the effects of reduced energy input could be large. A 70 quad scenario would then imply that the growth in real GNP would have to be held to virtually zero over the years 1970 through 2010!

ACCOMMODATING CAPITAL AND ENERGY

The analysis of substitution identifies an important element of the energy-economic interaction and illustrates the limits of the analogy of the elephant and rabbit stew. Several other deficiencies can be found in this model. The most serious may be the relationship between changed inputs of energy and the inputs of all other factors. It might be a reasonable first approximation to assume that labor inputs are undiminished by the changed availability of energy, even though their productivity declines. But the same may not be true for capital inputs. Reduced energy inputs will lower the marginal productivity of capital. This, in turn, may depress the rate of saving and the level of investment. This energy induced capital reduction will reduce further the level of output and GNP. Such indirect effects may be the most important component of the economic impact of energy scarcity.[†]

There are several paths to follow in complicating the analysis to accommodate the roles of capital, labor, and energy. Following a popular approach in the literature, we adopt the natural extension of the two-factor production function by assuming that R is a Cobb-Douglas function of the inputs of capital (K) and labor (L) ,

$$R = cK^{\alpha} L^{1-\alpha} , \qquad (18)$$

[†] We are indebted particularly to Dale Jorgenson for calling our attention to this issue and for his assistance in developing the argument. See footnote, p. B-9 regarding the closely related issue of energy-capital complementarity.

Table B-4

ECONOMIC IMPACTS OF ENERGY REDUCTIONS

(with constant energy costs and
constant capital and labor inputs)

σ	E	ENERGY PRICE TO CONSUMERS, INCLUDING Btu TAX P_E ($/10^6 Btu)	GNP CHANGE (billions of 1975 dollars) $\overline{GNP}$[†] (based on Btu tax)
.10	220	.80	0
	190	3.10	-27
	160	11.17	-197
	110	28.33	-1220
	70	29.85	-2366
.20	220	.80	0
	190	1.60	-11
	160	3.49	-59
	110	14.49	-405
	70	35.32	-1351
.30	220	.80	0
	190	1.28	-7
	160	2.18	-33
	110	6.56	-187
	70	20.04	-630
.50	220	.80	0
	190	1.06	-5
	160	1.47	-18
	110	2.97	-82
	70	6.74	-230
.70	220	.80	0
	190	.98	-4
	160	1.24	-12
	110	2.06	-52
	70	3.79	-131

[†] Energy tax induced change in GNP in the year 2010. Base value at 220 quads is $4400 billions.

where α is the share of payments to capital and $1-\alpha$ is the share of payments to labor. This yields a new production function of the form

$$Y = F(K,L,E) = \left[aE^{\frac{\sigma-1}{\sigma}} + b\left(cK^{\alpha}L^{1-\alpha}\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}} \quad . \qquad (19)$$

Given base values of K_0 and L_0 for an assumed α, the natural extensions of (15) - (17) determine b and c by equating the marginal productivities of capital and labor with their respective prices.

If K and L are held constant as E varies, this three-factor model duplicates the analysis of the previous section. As an alternative assumption, however, it may be assumed that P_K, rather than K, is held constant and the level of capital input is adjusted as the availability of energy changes. This maintains the return on capital and is a long-run proxy for the adaptation in capital that might be induced by the reduced use of energy. It should represent a lower bound for the level of capital input and an upper bound for the energy-capital induced economic impact.

In Table B-5 we present the relevant GNP and energy price estimates assuming that P_K is constant. The value of α is set at 0.35, L_0 is set at 1, and the initial input of capital stock is assumed to be 2.5 times the GNP. Figure B-3 illustrates the same calculations for the alternate capital assumptions, assuming the elasticity of substitution is 0.3. The reductions in capital input produce significant reductions in GNP. For $\sigma = 0.3$ and E = 110 quads, the reduction in GNP increases from 4% to 11%. The required tax, however, is reduced from \$5.76 to \$4.32. But the qualitative conclusion of the two-factor analysis is preserved. Reductions in energy availability produce less than proportional reductions in GNP. The changes in capital can be important, but the economic impact is most sensitive to the index of flexibility, the elasticity of substitution.

Table B-5

ECONOMIC IMPACTS OF ENERGY REDUCTIONS

(Production Function Analysis of Btu Tax)
(with constant energy costs, constant labor inputs,
and a constant rate of return on capital)

σ	E	ENERGY PRICE TO CONSUMERS, INCLUDING Btu TAX P_E (\$/10^6 Btu)	GNP CHANGE (billions of 1975 dollars) $\overline{\text{GNP}}$ † (based on Btu tax)
.10	220	.80	0
	190	2.21	-177
	160	5.06	-526
	110	12.74	-1471
	70	20.43	-2447
.20	220	.80	0
	190	1.47	-88
	160	2.80	-251
	110	8.21	-844
	70	17.59	-1755
.30	220	.80	0
	190	1.22	-60
	160	1.99	-155
	110	5.12	-496
	70	12.49	-1136
.50	220	.80	0
	190	1.04	-44
	160	1.42	-91
	110	2.75	-244
	70	5.86	-516
.70	220	.80	0
	190	.97	-43
	160	1.21	-77
	110	1.98	-170
	70	3.56	-316

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† Energy tax induced change in GNP in the year 2010. Base value at 220 quads is \$4400 billions.

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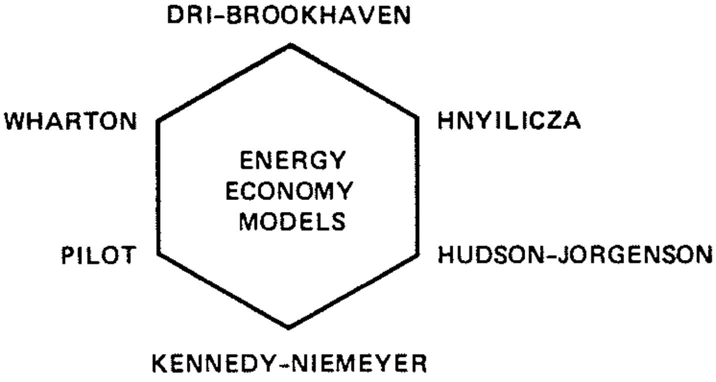
Appendix C

CAPITAL-ENERGY COMPLEMENTARITY IN AGGREGATE ENERGY-ECONOMIC ANALYSIS

The link between capital and energy is an important component of the full feedback effect of energy on the economy. The nature of this link is the subject of debate with conflicting evidence available in different studies. This issue is discussed here with a proposed resolution of the debate that leads to the simplified analysis in Appendix B and Volume 1 of this report.



CAPITAL-ENERGY COMPLEMENTARITY IN AGGREGATE ENERGY-ECONOMIC ANALYSIS

by

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Working Paper

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Appendix C

CAPITAL-ENERGY COMPLEMENTARITY IN AGGREGATE ENERGY-ECONOMIC ANALYSIS

> "We have arrived at the finding that we human beings do not, on careful examination, turn out to possess any one clear-cut notion of complementarity and substitutability."
>
> --Paul A. Samuelson [1]

INTRODUCTION

If capital and energy are substitutes, national policies intended to reduce the demand for energy may increase the demand for new capital investment, creating a need for higher levels of saving but mitigating the economic impact of the lowered energy use. If capital and energy are complements, national policies intended to reduce the demand for energy may reduce the demand for capital, lessening the pressure on savings but magnifying the economic impacts of the lowered energy use.

These simple alternatives seem to characterize a straightforward energy policy analysis issue and a standard problem in economic theory. An empirical or analytical determination of the nature of the link between capital and energy, complementarity or substitutability, should establish the qualitative impacts of future energy policies. The importance of the problem has motivated a number of empirical studies [2, 3, 4, 5, 6, 7], but the results of these studies and the discussions they have stimulated indicate that things may not be as simple as they seem. Conflicting estimates have been reported with capital and energy appearing as complements in some analyses [e.g., 2] and substitutes in others [e.g., 4]. Instances of capital and energy substitutability come to mind readily, such as the use of insulation or the introduction of waste heat recovery equipment, but complementarity between capital and energy seems counterintuitive when interpreted in the context of specific engineering examples. This leads frequently to a reluctance to accept models or analyses incorporating complementarity between capital and energy.

The pursuit of this issue is surprisingly difficult, but there is some comfort in Samuelson's observation above drawn from his survey of the development of complementarity in economic demand theory. The confusion is not new nor is it unique to energy applications. The difficulty stems from our usage of terms like complementarity and substitutability without resolving conflicting definitions or interpretations. This is recognized for example in Berndt and Wood [3], where a careful application of concepts is presented to resolve the apparent empirical differences between their earlier complementarity result [2] and the substitutability finding of Griffin and Gregory [4]. The presentation in [3] provides additional tests of the robustness of the complementarity result for U.S. manufacturing and clarifies its interpretation.

Berndt and Wood [3] do not address the extension of their result to an aggregate production function for the full economy. It is the purpose of the present paper to argue that the natural extension, the measurement of the Allen partial elasticity of substitution, is inappropriate for the aggregate production function. This leads to the proposal of an alternative definition of the link between capital and energy induced by changes in energy policy that captures the intuitive concept with the correct policy interpretation. The conclusions of this paper can be summarized as a series of seemingly contradictory statements:

- Capital and energy are substitutes in the intuitive sense implied by the specific engineering examples.
- Capital and energy may be complements in the sense measured by the Allen partial elasticity of substitution.
- The Allen partial elasticity of substitution is not the relevant parameter for the design of aggregate national policies which have a pervasive effect on factor prices.
- For aggregate analysis, capital and energy should be viewed as complements in the sense that higher energy prices or reduced energy use will decrease the demand for capital. This reduced capital input may be the most important component of the economic impact of any energy restrictions.

THEORETICAL BACKGROUND

The argument in this paper employs the framework of a partial equilibrium analysis of an aggregate production function. The elegant theory of production functions and dual cost functions is collected in Diewert [8]. The essential elements are summarized here for later use.

The relationship between the inputs $X_1,\ldots,X_n$ and the gross output Y of the economy is assumed to be determined by a production function, F, defined on the positive orthant to be positive, concave, and homogeneous of degree one, i.e.,

$$Y = F(X);$$

$$F(X) > 0 \text{ for } X > 0, \left(X = (X_1,\ldots,X_n)\right);$$

$$F(\lambda X^1 + (1-\lambda)X^2) \geq \lambda F(X^1) + (1-\lambda)F(X^2) \text{ for } \lambda\varepsilon[0,1];$$

and

$$F(\alpha X) = \alpha F(X) \text{ for } \alpha\varepsilon[0,\infty].$$

If P_i is the price of X_i and the producer is in competitive equilibrium, then there exists a corresponding cost function $C(Y,P)$ that determines the minimum cost of producing output Y in the presence of prices P, i.e.,

$$C(Y,P) = \text{Min} \left\{PX \mid X > 0,\ F(X) = Y\right\}. \tag{1}$$

The cost function is positive on the positive orthant, concave, and homogeneous of degree one in P, and homogeneous of degree one in Y.

If F exhibits strictly convex isoquants (i.e., diminishing marginal rates of substitution) then the optimal solution to (1) is unique and is represented as

$$X^* = X^*(Y,P). \tag{2}$$

This defines the constant output demand as a function of factor prices. With appropriate differentiability assumptions, Shephard's lemma provides

$$X_i^*(Y,P) = \frac{\delta C(Y,P)}{\delta P_i}. \tag{3}$$

Interpreting the unit cost $C(1,P)$ as the price of output, P_Y, then the analogous result applies in terms of the gradient of the production function, equating prices and marginal productivity,

$$F_i = \frac{\delta F(X^*)}{\delta X_i} = P_i/P_Y. \tag{4}$$

These dual relationships are central to the analysis of the production function and in the simulation of a partial equilibrium analysis of the economy. The demand functions (3) are also important in the interpretation of the complementarity and substitutability concepts. The usual formal definitions of these terms employ the partial elasticities of substitution as defined in Allen [9]. Uzawa [10] has shown that this Allen partial elasticity of substitution (A.E.S.) between input factors i and j ($i \neq j$), denoted as σ_{ij}, may be written as

$$\sigma_{ij} = C(1,P) \frac{C_{ij}}{C_i C_j} , \tag{5}$$

where

$$C_i = \frac{\delta C(1,P)}{\delta P_i}, \quad C_{ij} = \frac{\delta^2 C(1,P)}{\delta P_i \delta P_j} .$$

According to this definition, factor inputs i and j are classified as substitutes or complements according to whether σ_{ij} is positive or negative.

The index σ_{ij} has a certain natural appeal in that it is symmetric, $\sigma_{ij} = \sigma_{ji}$, but it lends itself to an immediate interpretation when related to the price elasticity of demand for factors of production. The price elasticity of demand defined as

$$E_{ij} = \frac{\delta \ln X_i^*}{\delta \ln P_j} . \tag{6}$$

Normalizing for the scale of output, it follows from (3) that

$$E_{ij} = s_j \sigma_{ij}, \tag{7}$$

where s_j is the share of factor payments going to j,

$$s_j = \frac{P_j X_j^*}{C(Y,P)} .$$

This price elasticity of demand is not in general symmetric, $E_{ij} \neq E_{ji}$, but it has the same sign as the A.E.S. Hence, holding output constant, two input factors i and j are A.E.S. complements if an increase in the price of j reduces the demand for i or A.E.S. substitutes if an increase in the price of j increases the demand for i.

This definition seems satisfactory enough and appears to be consistent with the intuitive notions of complementarity and substitutability. The A.E.S. is the concept most frequently used and the focus of the major empirical studies cited above. For $n > 2$, however, the A.E.S. is not as simple as it appears. The sign of σ_{ij} depends very much on the nature of the production function in terms of factors other than X_i and X_j. Semantic confusion arises because complementarity is not a generalization of the concept of perfect complements familiar in two dimensional analysis. More subtle confusions stem from the dependence of the definition of the A.E.S. on changes in one price holding output and all other factor prices constant. It seems worthwhile to develop further an interpretation of the A.E.S.

INTERPRETING CAPITAL-ENERGY COMPLEMENTARITY

Samuelson [1] documents the historical difficulty of economic theory in producing an acceptable formal definition of complementarity that preserves intuitive appeal. This confusion is found in specializations of the concepts to the study of capital and energy. A review of the empirical debate can be found in Berndt and Wood [3]. Examples of ambiguous interpretations of A.E.S. complementarity are present in Sonenblum [11] or Chapman [12]. In fact, the presentation by Berndt and Wood [3] seems to be a rare but successful attempt to explain the concepts in a straightforward and self-consistent manner in the context of capital and energy. We present a similar interpretation here that supplements their exposition without invoking translog approximations to the cost function. Convenient for empirical implementation, this translog approximation is not essential to the interpretation of the A.E.S.

The first step is to dispense with one natural source of potential confusion in the use of the terminology. Figure C-1 recalls the familiar definitions of perfect complements and perfect substitutes in a production function with two inputs and one output. If the isoquant for the production function is represented by a-a, then the two inputs X_1 and X_2 are often referred to as perfect complements. If the correct isoquant is b-b, however, the two inputs are then referred to as perfect substitutes. It is important to recognize that the A.E.S. definition of complementarity or substitutability is not a natural generalization

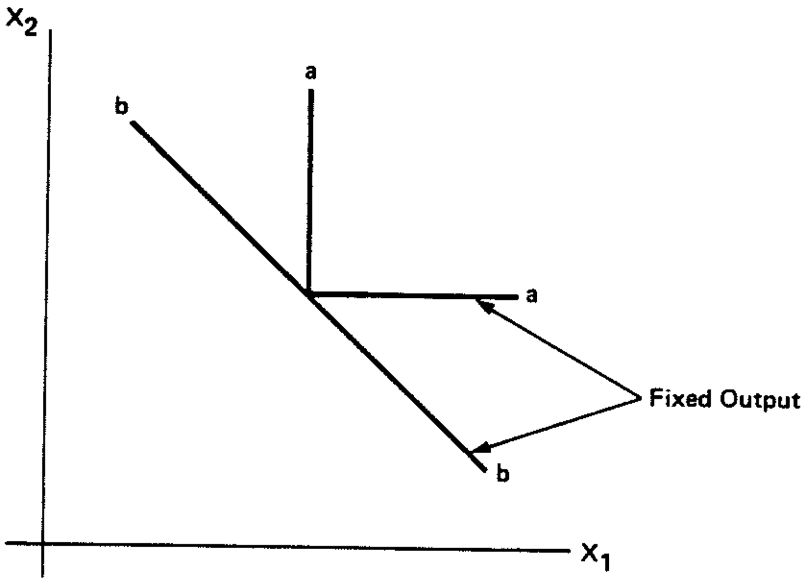

Figure C-1 Traditional Interpretation of Perfect Complements and Perfect Substitutes of this common usage. In fact when $n = 2$, the A.E.S. is always nonnegative and the two goods must be substitutes. For $n > 2$, it is not in general possible to determine the sign of the A.E.S. by examining the two dimensional projection of a single isoquant. Recognizing that the A.E.S. refers to a different property of the production function goes a long way toward dispelling the counterintuitive aura of A.E.S. complementarity.

To see the correct interpretation of the A.E.S., at least a three factor production function is necessary and this presents the opportunity to begin the specialization to the discussion of capital and energy. For simplicity, the aggregate production function for the economy is represented in terms of three inputs: capital, labor, and energy, $Y = F(K,L,E)$.[†]

The assumption that F displays diminishing marginal rates of substitution or has strictly convex isoquants implies that the projections of the isoquants are also strictly convex. This is illustrated in Figure C-2 where the three possible pairs of isoquants are depicted holding output and the input of the third factor constant. Hence, in Figure C-2a if output and labor input are held constant, the locus of all pairs of capital and energy that are possible describes a standard isoquant familiar from the traditional two dimensional example. When output and labor inputs are held constant, capital and energy are seen to be substitutes. This follows directly from the concavity assumptions for the production function. The analogous results in Figures C-2b and C-2c hold for capital and labor or labor and energy. Taken two at a time, the factors always are substitutes on any isoquant.

This two dimensional substitution seems consistent with the engineering examples of insulation or waste heat recovery. To maintain the same level of output in any productive process, holding the inputs of other factors constant, it follows immediately that capital and energy are substitutes. There is no conflict here with engineering intuition. The economic assumptions underlying the aggregate production function conform with the natural intuition about the physical process.

This qualitative characteristic of the production function tells us nothing about the degree of substitution between any two factors. It may be that capital and

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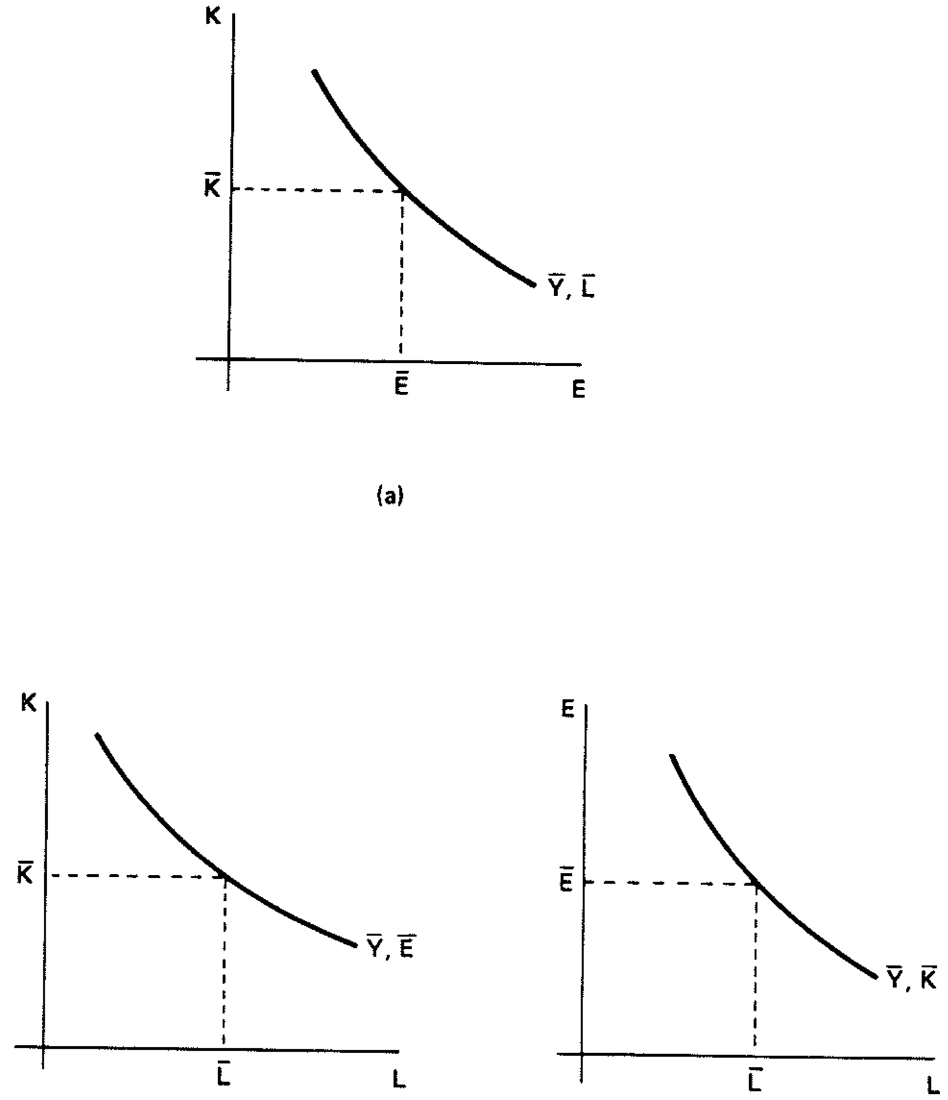
[†] Berndt and Wood represent $Y = F(K,L,E,M)$ for the manufacturing sector. Which of these is a preferred approximation for the aggregate production function is an empirical question. The conceptual discussion applies equally to both.



(a)

(b)

(c)

Figure C-2 Two Factor Isoquants Implied by Concave Three Factor Production Function energy are relatively weak substitutes but energy and labor are very strong substitutes. It is this notion, the degree of relative substitution, that is the key to the interpretation of the A.E.S. Consider, for example, the situation in Figure C-3a, which shows the isoquants for the production function with inputs K_1, L_1, and E_1 producing output $\overline{Y}$. The slope of the isoquant at this point is $-P_E/P_K$. Now suppose that the price of energy increases slightly, shifting the slope from line A to line B. The movement along the isoquant $\overline{Y}$, L_1 would increase the demand for capital to K_2 and decrease the demand for energy to E_2. But the rise in the price of energy also causes some shift in the demand for labor--say to level L_2. This causes a shift in the projection of the capital energy isoquant to the dashed line $\overline{Y}$, L_2. The cost slope parallel to line B is now line C, tangent to the new isoquant at the point K_3, E_3. This is the final equilibrium point. The energy demand has decreased in the two steps and the movement between isoquants has reduced the demand for capital. In this case the reduction compensates for the increase in capital that occurred while substituting away from energy along the original isoquant. Hence, the final demand for capital is reduced as a result of an increase in the price of energy. This implies a negative cross price elasticity $E_{KE} < 0$. It follows from the definitions that the A.E.S. between capital and energy is negative. Capital and energy are A.E.S. complements in Figure C-3a. The opposite situation is depicted in Figure C-3b, where the shift between isoquants reduces capital demand, but not enough to compensate for the substitution between capital and energy. In this case the elasticity of demand for capital with respect to the price of energy is positive and the A.E.S. between capital and energy is positive. Capital and energy are A.E.S. substitutes in Figure C-3b.

It is clear from these examples that the A.E.S. is a measure of the relative substitution between two factors compared with the substitution effects of other input factors. If the substitution between capital and energy is large compared to the substitution between their composite and labor, then capital and energy are seen as A.E.S. substitutes. When the substitution between capital and energy is relatively small compared to the substitution of their composite with labor, then capital and energy are seen as A.E.S. complements. Berndt and Wood [3] have given these two relative components of the total elasticity the names <u>gross substitution effect</u> and <u>scale effect</u>. A movement along the isoquant with higher energy prices is the gross substitution effect with capital always substituting for energy. The movement between isoquants, the scale effect, further reduces the demand for energy and reduces the demand for capital. If this scale

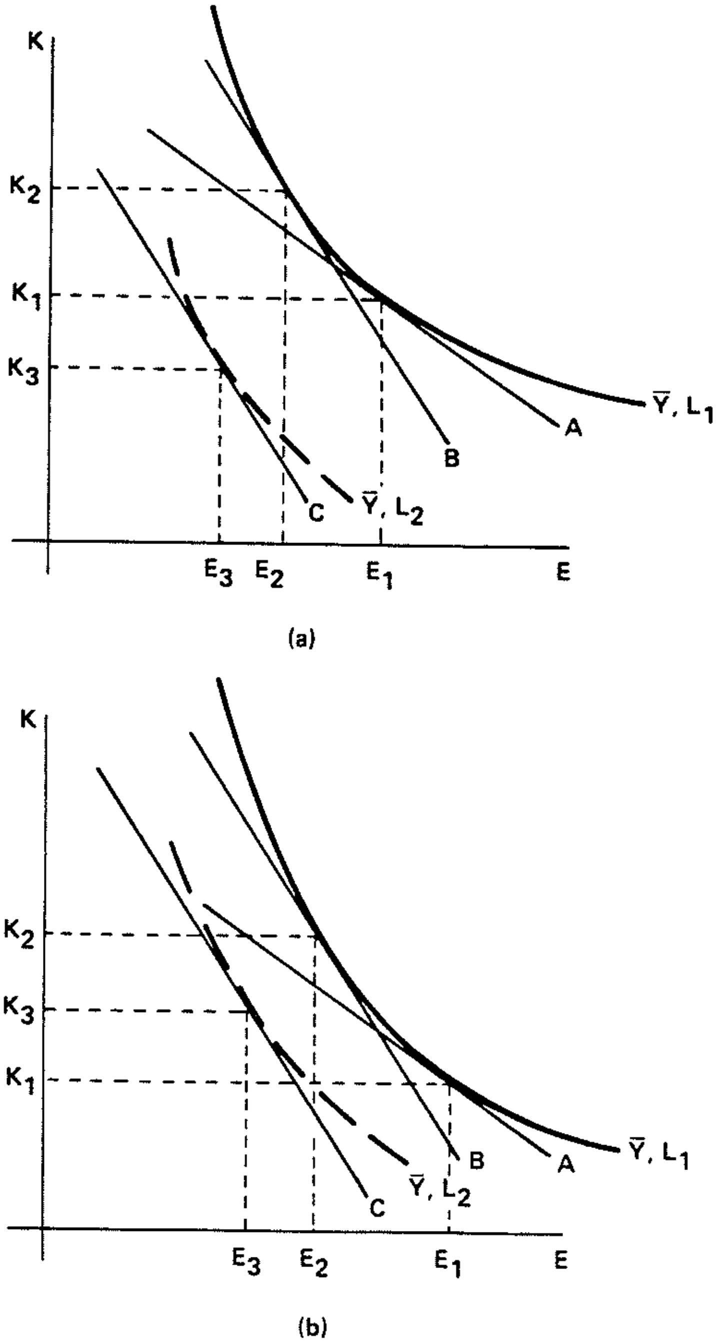


Figure C-3 Illustration of A.E.S. Complementarity (a) and Substitutability (b) for Capital and Energy effect is larger than the gross substitution effect for capital, then capital and energy are net complements or A.E.S. complements. If the scale effect is less than the gross substitution effect, then capital and energy are net substitutes or A.E.S. substitutes. Berndt and Wood [3] present these examples using a translog approximation to a hierarchical version of their production function. As we have seen, this specialization is not required for the conceptual interpretation. However, it does permit a derivation of formulas for the scale and gross substitution effects that can be tested empirically. Berndt and Wood estimate these parameters and conclude that, for capital and energy in their production function for total U.S. manufacturing, the scale effect dominates the gross substitution effect and capital and energy are A.E.S. complements.

This result can be made intuitively appealing in the context of the aggregate $F(K,L,E)$ production function by imposing what appears to be a restrictive assumption on the form of the relationship. Suppose that the production function is a hierarchical function of the form $F(K,L,E) = G(H(K,E),L)$. Here it is assumed that both G and H are constant elasticity of substitution production functions. It follows that K and E are substitutes in H with H and L being substitutes in G. This would seem to be so restrictive as to guarantee substitution between K and E in F. It is curious to note, however, that K and E can be A.E.S. complements in F. The A.E.S. between capital and energy, σ_{KE}, is shown by Sato [13] to be

$$\sigma_{KE} = \sigma_G + \frac{1}{s_H} (\sigma_H - \sigma_G) ,$$

where σ_H and σ_G are the elasticities of substitution in the C.E.S. functions H and G respectively, and s_H is the value share of H in G. The first term can be interpreted as the substitution effect and the second term as the scale effect. Hence, after rearranging terms if $\sigma_G \geq \sigma_H/(1-s_H)$, then the capital and energy are A.E.S. complements in F.

A stylized version of the values of the parameters might have G as a Cobb-Douglas function, $\sigma_G = 1$, with the share going to H equal to 0.26. Hence, if the elasticity of substitution between capital and energy in H is less than 0.74, then capital and energy are A.E.S. complements in F. Now the marginal productivity relationship for this specification of F yields

$$\ln E = C_1 + \sigma_H \ln\left(\frac{Y}{H}\right) + \ln H - \sigma_H \ln(P_E/P_Y).$$

Ignoring the effects of energy on H and Y, therefore, $-\sigma_H$ is the partial own price elasticity of energy demand. Although the feedback effects on H and Y make this interpretation less than precise, it would seem more likely that $\sigma_H < .74$ in light of the conventional wisdom about the own price elasticity of the aggregate demand for primary energy [14].

This restrictive functional form is not recommended for empirical investigation. The argument is sufficient, however, to establish the first two propositions presented in the introduction.

The assumption of concavity of F implies that capital and energy are substitutes when viewed in isolation from the rest of the inputs to the productive process. Capital and energy isoquants exhibit the normal substitution relationship consistent with the intuition produced by the engineering examples. And this finding of substitution in the engineering sense is not in conflict with the possibility of a determination that capital and energy are A.E.S. complements in the context of the aggregate production function. This is essentially an empirical question. There seems to be nothing counterintuitive about A.E.S. complementarity. In fact, a plausible case for capital and energy complementarity can be constructed within the context of a seemingly restrictive hierarchical production function which imposes substitution at each level in the hierarchy. From this perspective the possibility of A.E.S. complementarity between capital and energy seems appealing, even likely. In the next section this possibility is examined further leading to a different question: Is A.E.S. complementarity between capital and energy important?

RELEVANCE OF A.E.S.

The previous section supports the conceptual possibility of A.E.S. complementarity between capital and energy. A determination that capital and energy are A.E.S. complements would seem to have immediate implications for national energy policy. For example, Berndt and Wood [3] are concerned with the likely energy demand impacts of a general investment tax credit and conclude that such a stimulation of investment would increase energy demand. In a similar vein, the economic effects of a reduction in the use of energy via higher energy prices are sensitive to the changes in capital investment induced by the higher energy costs. This economic impact is the main concern of the present discussion. The importance of the link between capital and energy in this regard can be demonstrated within an elementary framework.

The approach follows that of Hogan and Manne [15]. The output of nonenergy goods in the economy (Y) is assumed to be determined by the inputs of capital (K), labor (L), and energy (E) to the production function (F),

$$Y = F(K,L,E), \tag{8}$$

where F is a positive, differentiable, concave function exhibiting constant returns to scale and diminishing marginal rates of substitution. This notion carries implicit assumptions about the accounting conventions for the production and use of energy and nonenergy goods. Energy is treated as an intermediate product contributing to the ultimate production of goods and services for final demand. This might be the case if the consumer is viewed as demanding the services of energy, rather than the energy per se, and if all the products and services of the nonenergy sector can be aggregated into a single output index, Y. This output is measured in the same units as the GNP. The standard identities equating the value of input and output yield

$$P_Y Y = P_K K + P_L L + P_E E, \tag{9}$$

and

$$P_Y \ GNP = P_K K + P_L L . \tag{10}$$

The interindustry transactions for this accounting convention are displayed in Table C-1.

Assuming a competitive solution, at any given level of output there must be equality between the price of inputs and their marginal productivities, i.e.,

$$F_K = \frac{\delta F}{\delta K} = P_K/P_Y ,$$

$$F_L = \frac{\delta F}{\delta L} = P_L/P_Y , \tag{11}$$

and

$$F_E = \frac{\delta F}{\delta E} = P_E/P_Y .$$

Table C-1

INTERINDUSTRY TRANSACTION FLOWS
IMPLICIT IN F(K,L,E) ACCOUNTING

TO / FROM	ENERGY	NONENERGY	FINAL DEMAND
ENERGY	0	$P_E E$	0
NONENERGY	$P_E E$	0	GNP
CAPITAL	0	$P_K K$	
LABOR	0	$P_L L$	

Finally, the unit cost function dual to (8) gives

$$P_Y = C(1, P_K, P_L, P_E). \tag{12}$$

For any specific form for the production function in (8), this simple partial equilibrium model can be solved for the changes in GNP that are produced by changes in energy use given the related changes in other input factors [15]. The full solution is not necessary, however, to demonstrate the importance of the link between capital and energy. From (11) it follows that

$$\frac{F_K K}{Y} = \frac{P_K K}{P_Y Y} = s_K \tag{13}$$

$$\frac{F_E E}{Y} = \frac{P_E E}{P_Y Y} = s_E , \tag{14}$$

where s_K and s_E are the value shares of capital and energy respectively. The left-hand side of (13) and (14) also are the elasticities of output with respect to the inputs of capital and energy. Adapting to our accounting system the data from Denison [16] for capital and labor shares of GNP and the Bureau of Mines [17] for energy expenditures, we have approximate values of $s_K = .22$ and $s_E = .04$ prior to 1960. Changes in capital, therefore, have a greater impact on the gross output than do changes in energy alone.

A reduction in the use of energy by itself will have a relatively small economic impact, determined to first order by energy's small value share. But if the reduced use of energy also produces a reduction in the use of capital, the larger value share of capital applies and the economic impact is magnified. This indirect effect through capital can be the largest component of the economic impact of reduced energy use, e.g., see [15] and [14], but this effect is often ignored in economic impact analyses of energy policy, e.g., [18].† A common approach used to sidestep the difficulty is to assume the existence of compensating policy

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† The published results of Hudson and Jorgenson [5] display slight increases in aggregate capital services for small increases in the price of energy through 1980. However, Jorgenson has indicated privately that more recent executions of a later version of the model produce significant reductions in the capital services that cause the major component of the reduction in GNP.

or serendipitous supply behavior that maintains the capital input. But what if such assumptions do not hold? How does a change in energy use affect the use of capital?

From the policy perspective, the final answers to these questions must be found in the new equilibrium solution for the full economy. A reduction in energy use will reduce output and change both the ability and willingness to save. At the same time, the reduced use of energy will change the demands for capital as an input to the productive process. Even more indirect effects through changes in labor may occur as the system evolves over time. To be complete, an analysis of the link between capital and energy should include the supply and demand effects contained in a general equilibrium system.

This requires the construction and use of a complete growth model with specific energy sectors, as in [5, 6, 19, 20, 21]. Correct in principle, this approach can be complicated to implement and, by itself, difficult to interpret. There is a natural interest in a transparent aggregation that tracks and explains the full equilibrium result.

A number of approaches are available for a simple partial equilibrium model. The choice of inputs (K,L,E) in (8) determines output Y and the prices in (11). By duality relationships between production and cost functions, the prices and output levels could be specified to determine the demand for input factors. Alternative approaches to the solution can be taken by specifying appropriate combinations of prices and outputs and solving (8) - (12) for the remaining variables. A reduced input of energy implies a higher marginal productivity and, therefore, by (11) a higher equilibrium price. The effect on capital of reduced energy use, therefore, might be determined through an investigation of the change in capital demand induced by a change in energy price, i.e., the elasticity of capital demand with respect to energy price.

This approach through prices seems natural, particularly when the production function is interpreted in the context of a single firm. The firm is a price taker adjusting its demand for inputs in response to changes in the factor prices. A change in the price of energy for a single firm should not affect the price of other inputs. If demand for the firm's output is inelastic, the partial equilibrium result will approximate the general equilibrium solution. Factor demand response to an energy price change, therefore, can be measured along a given isoquant with other factor prices held constant. This is the constant output price elasticity and, as discussed above, the sign of the response is revealed by the A.E.S. For a single firm, therefore, the A.E.S. is an appropriate and simple measure of the link between capital and energy.

The single firm may observe a change in the price of energy without seeing related changes in the prices of other input factors. The increase in energy prices does increase P_Y , the price of output for the firm, but this small change for one firm should not affect prices in the full economy. It is reasonable to presume that the real prices of capital and labor remain constant in terms of the goods and services they represent. For a single firm, the suppliers of capital and labor should be willing to provide any level of input at the constant real price. The assumptions implicit in the definition of A.E.S. should be satisfied for a single firm. The aggregation to the full economy, however, alters this situation. At the level of the aggregate production function there is no distinction between P_Y and the price of output for the full economy. If the energy price increases for the entire economy, then P_Y increases and the amount of goods and services that can be obtained for P_K and P_L declines. Maintaining constant P_K and P_L in the presence of an aggregate increase in the price of energy implies a decline in the real price of capital and labor. Certainly this change will affect the aggregate supply of factors as well as the demand. In particular, the assumption of a perfectly elastic supply of labor is no longer applicable. The A.E.S. test, therefore, loses appeal as the proxy for the general equilibrium result when the analysis moves beyond the case of a single firm. Some extension is needed to deal with the aggregate production function. The adaptation suggested in the next section consists of a change in the question presented to the model.

A TEST FOR AGGREGATE CAPITAL AND ENERGY

In most long run economic growth models, the supply of labor is exogenous, or at least very inelastic [22, 5, 6, 19, 21]. This seems appropriate in the aggregate analysis, unlike the case for the single firm, and is adopted here. If the supply of labor is fixed, then a change in the use of energy and capital must change the equilibrium price of labor in real terms.

A similar situation exists for capital inputs. Changes in energy input will change the marginal productivity of capital and may affect over time the willingness of the economy to save and invest. The choice of an approximation for this equilibrium behavior of capital supply and demand is problematical. Three alternatives suggest themselves as convenient simplifications: perfectly inelastic capital supply, a constant savings rate, and perfectly elastic capital supply. The assumption of a perfectly inelastic supply seems implausible without some compensating fiscal policy. In any event it makes the investigation of the link between capital and energy moot and, therefore, is not pursued here. An assumption of a constant savings rate would imply a complementary relationship between capital and energy but a very weak one with little aggregate effect on the equilibrium solution.[†] This is inconsistent with the argument above that the link between capital and energy may be the most important component of energy scarcity. The most plausible approximation, therefore, is continuation of the assumption implicit in the analysis of the individual firm, a perfectly elastic supply of capital at the equilibrium price of capital. But now the real price of capital is interpreted as P_K/P_Y rather than P_K. With this assumption, capital inputs adjust to maintain F_K, the marginal productivity of capital.[††] A change in the use of energy will change the use of capital and, with a fixed supply of labor, produce changes in the real energy price, the real labor price, and the gross output.

This partial equilibrium simulation of (8) - (12) is proposed as the approximation to the general equilibrium solution. It is intended to provide a policy relevant definition of the link between capital and energy applicable to the aggregate

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[†] In terms of elasticities, the total change in output induced by a change in energy, $\hat{\eta}_{Y,E}$, must satisfy

$$\hat{\eta}_{Y,E} = \eta_{Y,K}\, \eta_{K,GNP}\, \eta_{GNP,E} + \eta_{Y,L}\, \eta_{L,E} + \eta_{Y,E} .$$

By assumption, $\eta_{L,E} = 0$. With a fixed savings rate, $\eta_{K,GNP} = 1$. It is clear that $\eta_{GNP,E} \leq \hat{\eta}_{Y,E}$. Therefore, under these conditions, $\eta_{Y,E} \leq \eta_{Y,K}\, \eta_{Y,E} + \eta_{Y,E}$. But $\eta_{Y,K} = s_K$ and $\eta_{Y,E} = s_E$. Hence, $\hat{\eta}_{Y,E} \leq s_E/(1-s_K)$, very close to the situation when there is no link between capital and energy for which $\hat{\eta}_{Y,E} = s_E$.

[††] The use of a constant F_K across alternative paths of the equilibrium economy is an ad hoc procedure. It may be motivated as in Burmeister and Dobell [22, pp. 38-43], who discuss the case of monetary forces outside the model maintaining the real rate of interest to produce a constant F_K, although this presents some difficulties with their simple savings functions. If the long run equilibrium growth paths are also balanced growth paths in an optimal economic growth setting, then the assumption of a constant F_K applies. (See Appendix.) Ultimately, of course, this simplification and the resulting test depend upon their faithfulness as an approximation for the general equilibrium solution.

production function much as the A.E.S. applies to the analysis for an individual firm. If capital demand moves in the same (opposite) direction as the energy input in this simulation, then capital and energy are defined to be aggregate complements (substitutes).[†]

It is an unfortunate circumstance of terminology that the nature of the link between capital and energy in the sense suggested here is determined by the sign of the partial elasticity of complementarity as found in Sato and Koizumi [23,24], reinforcing the semantic confusion. To mitigate these problems, it is better to follow Samuelson's [25] insight and investigate aggregate complementarity (substitutability) in terms of the second derivatives of the production function, F_{ij} . The simulation of the model for this test can be performed in two stages as shown in Figure C-4. First, reduce the energy input to some new lower level, say from E_1 to E_2 . Second, adjust the capital input to maintain the real price of capital P_K/P_Y or, equivalently, the marginal productivity, F_K . By the concavity assumptions, it follows that $\delta^2F/\delta K^2 = F_{KK} < 0$. If the necessary adjustment of capital is an increase to K_2' , then it must be that the reduction in energy increased F_K , implying that $F_{KE} < 0$. If the necessary adjustment of capital is a decrease to K_2'' , then it must be that the reduction in energy decreased F_K , implying that $F_{KE} > 0$.

The operational test of the definition of the link between capital and energy, therefore, reduces to the determination of F_{KE} with positive values implying that reduced capital accompanies reduced energy (aggregate complementarity) and negative values implying that increased capital follows reduced energy (aggregate substitutability).

What is the value of F_{KE} for the American economy? This is an empirical issue but we might gain some insight by investigating alternative _a priori_ specifications of (8). Consider the case of a hierarchical production function where capital and labor combine in a Cobb-Douglas function which in turn combines with energy in a C.E.S. production function, e.g.,

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[†] The use of the terms complementarity and substitutability in this new sense seems as dangerous as it is attractive. Note that the definition requires the third input, labor, to absorb the reduction in real output. The specialization to the case with only two inputs seems vacuous. The extension to more than three inputs requires increasingly heroic assumptions about the adequacy of the approximation to the general equilibrium solution. There has been no attempt to make the test symmetric for policy changes imposed on capital rather than energy.

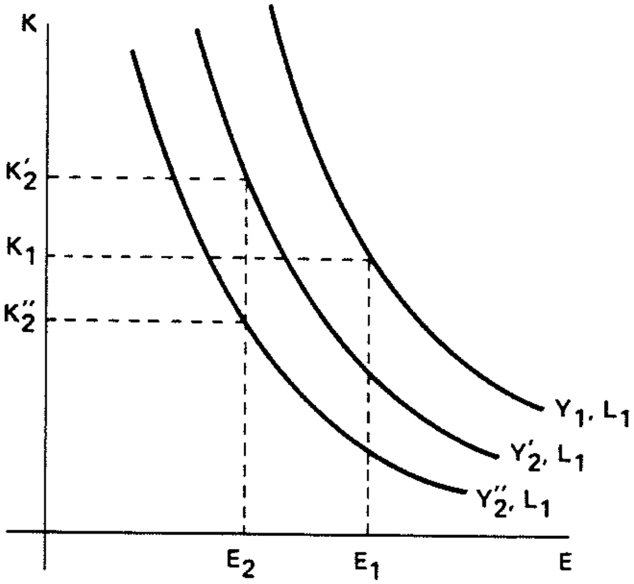

Figure C-4 Capital Adjustments to Energy Reductions to Maintain Constant Rate of Return with Final Labor Input

$$F(K,L,E) = G(H(K,L),E), \qquad (15)$$

with

$$G(H,E) = \left[aH^{(\sigma-1)/\sigma} + bE^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)},$$

$$H(K,L) = cK^{\alpha} L^{1-\alpha},$$

and

$$(\sigma > 0;\ \sigma \neq 1, \infty;\ \alpha \varepsilon (0,1);\ a,b,c > 0).$$

Sato [13] gives the A.E.S. between capital and energy in this case as $\sigma_{KE} = \sigma > 0$. Hence, capital and energy are A.E.S. substitutes. Direct differentiation of (15) yields

$$F_{KE} = \frac{\alpha abH}{G\sigma K}\left(\frac{G^2}{HE}\right)^{1/\sigma}, \qquad (16)$$

and, therefore, $F_{KE} > 0$. In the simulation test of the aggregate production function, therefore, a reduction in energy always produces a reduction in capital, aggregate complementarity, despite the fact that capital and energy are always A.E.S. substitutes.

To introduce the possibility of A.E.S. complementarity between capital and energy, an alternative hierarchical specification might be

$$F(K,L,E) = H(G(K,E),L), \qquad (17)$$

with

$$H(G,L) = cG^{\alpha} L^{1-\alpha},$$

$$G(K,E) = \left[aK^{(\sigma-1)/\sigma} + bE^{(\sigma-1)/\sigma}\right]^{\sigma/(\sigma-1)},$$

and

$$(\sigma > 0;\ \sigma \neq 1, \infty;\ \alpha \varepsilon (0,1);\ a,b,c > 0).$$

From Sato [13] again, the A.E.S. between capital and energy is now

$$\sigma_{KE} = 1 + \frac{1}{\alpha}(\sigma-1).$$

Hence, if $\sigma < 1-\alpha$, then capital and energy are A.E.S. complements. If $\sigma > 1-\alpha$, then capital and energy are A.E.S. substitutes. Differentiate (17) to obtain

$$F_{KE} = (\alpha - 1 + \frac{1}{\sigma}) \left[\frac{\alpha abH}{G^2} \left(\frac{G^2}{EK}\right)^{1/\sigma} \right] . \qquad (18)$$

Therefore, $F_{KE} > 0$ if

$$\sigma < \frac{1}{1-\alpha} ,$$

but $F_{KE} < 0$ if

$$\sigma > \frac{1}{1-\alpha} .$$

For this specification of the production function, a finding of A.E.S. complementarity is sufficient but not necessary for aggregate complementarity. Further, only when capital and energy are very strong substitutes does aggregate substitutability occur. For example, if

$$\sigma > \frac{1}{1-\alpha} ,$$

then

$$\sigma_{KE} = 1 + \frac{1}{\alpha}(\sigma - 1)$$

$$> \frac{2-\alpha}{1-\alpha} ,$$

where α is the share of payments to capital and energy. The shares in the Berndt and Wood [2] results for U.S. manufacturing, normalized for the $F(K,L,E)$ formulation, have $\alpha = .26$, implying a $\sigma_{KE} > 2.36$, far from their empirical finding of $\sigma_{KE} < 0$. For the $F(K,L,E)$ formulation of Griffin and Gregory [4] with OECD data, Berndt and Wood [3] report $\alpha = .46$, implying a $\sigma_{KE} > 2.85$. This compares poorly with the Griffin and Gregory estimate of $\sigma_{KE} \simeq 1.00$. If (17) is accepted as a reasonable approximation to the more flexible translog forms used in these empirical studies, and if the results for the manufacturing sector extend to the full economy, then we must conclude that $\sigma < \frac{1}{1-\alpha}$ and $F_{KE} > 0$.

These alternative examples for the production function illustrate the importance of the role of substitution with respect to the third input, labor, as well as indicating that we are unlikely to find $F_{KE} < 0$. It cannot occur in (15) and occurs in (17) only for large values of σ.

This completes the arguments for the third and fourth propositions presented in the introduction. For the aggregate production function, the A.E.S. test is not relevant. The conditions of the A.E.S. interpretation cannot be met in the simulation of the aggregate production function. An alternative definition and test for the link between capital and energy are needed. The proposal here is motivated by an effort to obtain a simple partial equilibrium analysis as an approximation to the correct general equilibrium solution in the presence of restricted energy availability. For this proposed test, the link between capital and energy is determined by F_{KE} with the probable value for the United States satisfying $F_{KE} > 0$. Hence, for the proposed definition of the link between capital and energy it is likely that reduced utilization of energy implies a reduced demand for capital in the aggregate production function. Energy and capital can be viewed in this sense as aggregate complements.

CONCLUSION

This paper seeks to clarify some conceptual issues regarding the nature of the link between capital and energy and implications for energy policy. It is demonstrated that the empirical findings of A.E.S. complementarity are not in conflict with the engineering examples of capital-energy substitution. The finding of A.E.S. complementarity is shown to be quite plausible and should not be an *a priori* reason for dismissing any economic model or policy analysis. But the importance of the A.E.S., positive or negative, is disputed. The conditions assumed for the interpretation of the A.E.S. cannot hold in an application to the aggregate economy. The policy relevant definition of the link between capital and energy should be the changes in the general equilibrium solution for capital induced by change in energy availability. If the assumptions of constant real returns on capital and exogenous labor supply are good approximations across the general equilibrium growth paths, then the link between capital and energy is determined entirely by the technology of the aggregate production function. Although empirical verification is necessary, it is argued that the likely link between capital and energy is one of aggregate complementarity. Restrictions on aggregate energy use should induce reductions in the demand for capital and, therefore, exacerbate the economic impacts of the energy policy. The corresponding effects on energy induced by changes in capital availability have not been addressed.

Appendix

CONSTANT RETURNS TO CAPITAL IN OPTIMAL GROWTH MODELS

The key assumption in the proposed definition of the link between capital and energy is that the equilibrium F_K remains constant across energy scenarios. The adequacy of this approximation remains as an empirical question for descriptive growth models. For optimal growth models, as in [20], the assumption can be investigated analytically. This can provide insight for the optimizing models and may generalize to descriptive models which include optimizing behavioral assumptions. The approach here is a standard application of optimal control theory [26]. Suppose there is a well defined cost function for the energy sector, M, measuring the real resources consumed in the production of energy level E. This could be a very general cost function tracking a complicated energy system. Here the cost is assumed to be dependent on the rate of production, cumulative energy production, Q, and possibly time, M(Q,E,t). Then the optimal growth problem might be formulated as

$$\max_{C,E} \int_0^T e^{-rt} u(C\cdot g)\, dt \tag{19}$$

$$\dot{K} = F(K,L,E,t) - C - M(Q,E,t) - \delta K$$

$$\dot{Q} = E$$

$$K(0) = K_0$$

$$Q(0) = Q_0$$

where

u: utility function over consumption
F: the aggregate production function, indexed over time to account for technological change
M: energy cost function
C: consumption
r: discount rate for utility
δ: replacement rate for capital
K: capital stock
L: labor input (exogenous)
E: energy production
Q: cumulative energy production
g: an exogenous function of time (e.g., $g = 1/L$).

All functions are assumed to be continuously differentiable.

The Hamiltonian for this optimal control problem is

$$H = e^{-rt} u(Cg) + \lambda(F(K,L,E,t) - C - M(Q,E,t) - \delta K) + \Theta E . \qquad (20)$$

Now, over the optimal trajectory,

$$\frac{\delta H}{\delta C} = e^{-rt} u'(Cg)\, g - \lambda = 0 \qquad (21)$$

and

$$\frac{\delta H}{\delta K} = \lambda(F_K - \delta) = -\dot{\lambda} . \qquad (22)$$

The time derivative of (22) yields

$$-re^{-rt} u'(Cg)\, g + e^{-rt} u''(Cg)(\dot{C}g + C\dot{g})\, g + e^{-rt} u'(Cg)\, \dot{g} - \dot{\lambda} = 0 . \qquad (23)$$

The combination of (21), (22) and (23) gives

$$F_K = \delta + r - \sigma(Cg)\left(\frac{\dot{C}}{C} + \frac{\dot{g}}{g}\right) - \frac{\dot{g}}{g} \qquad (24)$$

where $\sigma(Cg) = \frac{u''(Cg)}{u'(Cg)} Cg$, the elasticity of marginal utility.

The assumption of constant F_K across energy scenarios is equivalent to constant F_K across different M in (19). It follows from (24), therefore, that the assumption holds if and only if $\sigma(Cg) \left(\frac{\dot{C}}{C} + \frac{\dot{g}}{g}\right)$ is constant across different energy scenarios. This could occur, for example, if

- the utility, u, is linear in its argument, in which case $\sigma(Cg) = 0$; or
- the utility is isoelastic, $\sigma(Cg) = \sigma$, and the optimal growth path is a balanced growth path, i.e., $\frac{\dot{C}}{C} = \frac{\dot{L}}{L} + \frac{\dot{Z}}{Z}$, where Z is an index of labor augmenting technology change. Since Z and L are exogenous and, therefore, constant across different realizations of M, the rate of growth of consumption and, therefore, F_K are constant across realizations of M. Of course, F_K may change over time but this does not affect our assumption.

The existence of a balanced growth path in optimal growth models is a familiar topic and a condition that intuitively seems appealing for simulations across different energy scenarios. Without drastic changes in C, there is little violence to the model in the use of an isoelastic utility function. It seems plausible, therefore, to conjecture that a constant F_K across energy scenarios is a good approximation to the equilibrium condition in an optimal growth model, assuming the approximation is applied for a time far enough in the future to eliminate the dominant effects of initial conditions. In this case, the analysis of the model for a given energy scenario reduces to a partial equilibrium problem determined entirely by the characteristics of F.

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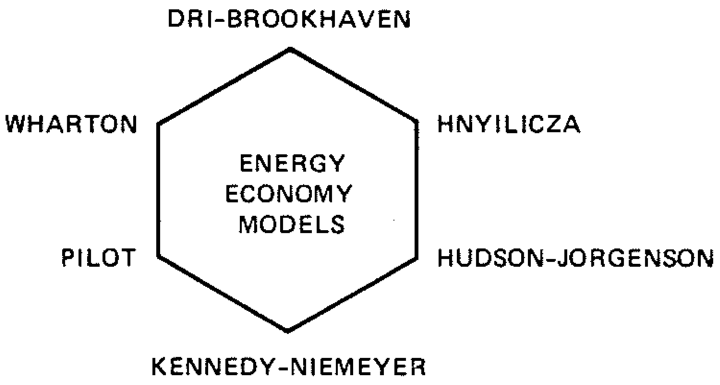
Appendix D

COMPARISON OF MODELS OF ENERGY AND THE ECONOMY

The six models addressed in the EMF study employ a diversity of methodologies and model detail. These models can be compared in many settings. For the purposes of the EMF study, examining the link between the energy sector and the remainder of the economy, the framework described here classifies the most important assumptions by exploiting the common accounting structure embedded in all six models.



COMPARISON OF MODELS OF ENERGY AND THE ECONOMY

by

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Working Paper

EMF 1.4

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Appendix D

COMPARISON OF MODELS OF ENERGY AND THE ECONOMY

INTRODUCTION

The Energy Modeling Forum seeks to improve the usefulness of formal models as aids for decision making by clarifying and communicating the capabilities of existing models. This investigation is pursued primarily through the evaluation of comparative tests of the models. These tests are constructed to explore and illuminate the basic structure of the participating models. This same structure can be explored through the independent review of the component model equations. The investigation of the equation structure is as basic to any systematic analysis as the review of model performance.

Varying degrees of documentation are available for the participating EMF models and these individual model descriptions are included as a separate part of the report. But the diversity of style and detail presents a challenge if the general character of the models is to be understood. Some simplified presentation, highlighting the key similarities and differences, is needed.

The models represented in the EMF working group address many issues beside the linkage between the energy sector and the remainder of the economy. Further, the conceptual orientations of the models differ and different components of the problem are emphasized. This diversity is valuable for our present study and is essential for the extension of the models to wider studies. When concentrating on the energy-economic feedback, however, a common structure of the models emerges. At the cost of ignoring some important individual model details, this common framework provides a background for designing and interpreting the comparative model tests. The purpose here is to develop this common framework and sketch the participating models in this context.

GENERAL STRUCTURE

The general framework derives from the familiar economic view of the circular flow of products and resources (Figure D-1). The many choices in this economy

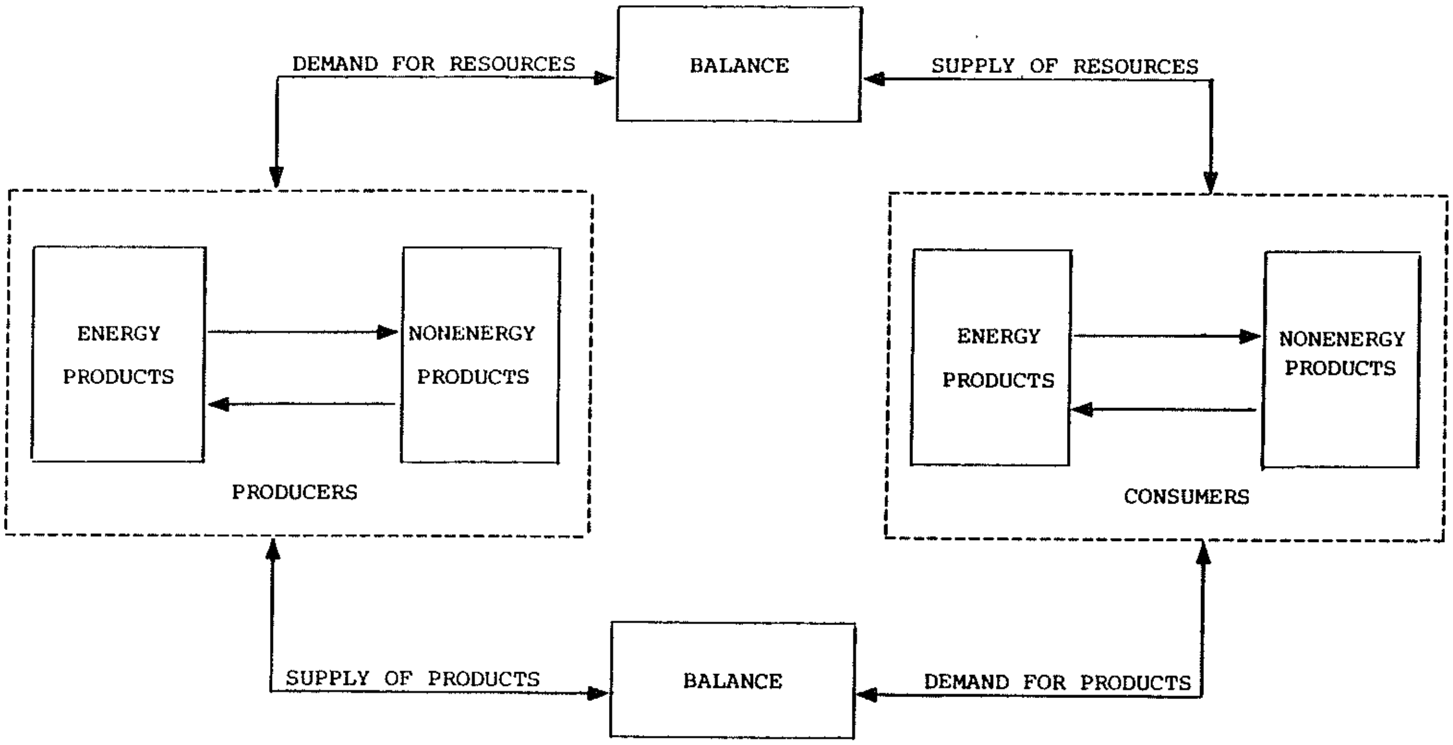

Figure D-1. Flow of Products and Resources are divided into the decisions made by two representative groups, the producers and the consumers.

The producers utilize the resources of the economy (e.g., capital, labor, and energy) to make products (e.g., gasoline and food). These products can be classified as energy and nonenergy products, each of which is provided directly for consumers or utilized in other production processes. The consumers in turn provide the economic resources to the producers and demand their products. The demands of consumers may be for energy or nonenergy products and there is an interaction between these components.

These dual relationships, the supply and the demand for resources and products, must be appropriately balanced. Each model has some implicit or explicit mechanisms for achieving this balance, and some of the most fundamental model differences can be found in the alternate descriptions of these interfaces. Once obtained, the balanced flow of resources and products is the primary measure of economic activity that can be compared to the level of energy utilization.

For the present discussion, certain features of the producers, consumers, and balancing mechanisms become prominent. These are the modeling characteristics which seem most relevant in explaining the different approaches to the modeling of the energy-economic feedback.

Producers

The models uniformly organize the production sector accounting through the use of an interindustry input-output structure. A major source of the demand for energy is the link in the production process where energy is an intermediate good used in the manufacture of other products. But the models differ in several features in the design of the input-output structure and the treatment of energy. These features are the level of aggregation, the degree of substitution, the representation of dynamics, and the incorporation of trends.

Aggregation. All the models distinguish between energy and nonenergy products, but the level of further disaggregation varies from none to a separate representation and accounting for more than 50 industrial groupings. Designed for different purposes, these varying levels of aggregation may provide some insight regarding the aggregate effects of possible changes in the composition of industrial output.

Substitution. A key element in the measurement of the feedback from the energy sector to the economy is the assessment of the flexibility of energy utilization in the production system of the economy. This flexibility can be broadly classified into two components: interfuel substitution and factor substitution. Inclusion of the interfuel substitution permits examination of those interactions where a conversion from one form of energy to another is important. On the other hand, the inclusion of factor substitution permits construction of scenarios depicting switches from energy to other factors of production (labor, capital, and intermediate goods and services).

The manner in which any of these two broad categories of substitutions is incorporated in the model also provides yet another source of model differences. Some substitution characteristics are implicit in the choice of the level of aggregation. Across the components of an aggregate, these implicit substitutions may assume either perfect substitutability or perfect complementarity. For example, in a model containing the aggregate "oil and gas", it is possible to assume either that "oil and gas" can meet any demand for either oil or gas (perfect substitutability) or that "oil and gas" can meet known fixed proportions of demands for oil and gas (perfect complementarity). The actual result may vary with different uses of the same model and may depend on how aggregate quantities are treated when exogenous changes are made. In a complex model where there are different levels of aggregation in different parts of the model, it is important to define the rules of disaggregation. This is seldom done.

The area where great care usually is taken is in describing the explicit substitutions across fuels or factors in the input-output structure. There are three prominent approaches: use of fixed coefficients (assumption of perfect complementarity), use of behavioral relations based on econometric analysis of historical data (econometric representation), and use of engineering descriptions of alternative process technologies (engineering representation). The possibilities for flexibility in the input-output coefficients are an important component of any flexibility in the energy-economy feedback and the source of some of the major differences in the model conceptions and implementations.

Dynamics. All the systems deal with the evolving economy in a dynamic framework, but the underlying dynamic structures differ among the models. Two attributes may be used to describe the differences across models: interaction of variables and speed of adjustment. The interaction of variables may be myopic, with current decisions determined entirely by current parameter values, or clairvoyant, with current decisions determined simultaneously by all parameter values. The dynamics of a model might permit instantaneous adjustment in variables resulting from exogenous shocks, or the adjustment may be gradual. In all the models, the key variable that forces some gradual adjustment is the stock of capital goods carried from one period to the next.

Trends. All of the models deal with some important exogenous parameters and structural changes through the application of simple trends. In this context, it is possible to define a standard set of variables that determines the long run growth of output in absence of any bottlenecks. This standard set consists of time profiles of population, labor force, and labor productivity.

Consumers

The models are less uniform in the accounting structure for final demand, but a similar set of characteristics provides a framework for describing the consuming sectors.

Aggregation. The level of product aggregation in each model consuming sector generally matches the corresponding level of aggregation in the production sector. However, these components of final demand are separated further into different types of consumption activities, investment groupings, classes of government expenditures, and types of net exports. Further, in some models the demands are estimated directly and in others they are derived from more fundamental end use requirements. As in the production sector, the level of detail here may permit examination of the effects of changes in the composition of final demand.

Substitution. A set of substitution characteristics parallel to those defined for producers is found in the structure of final demand. Thus, it is possible to broadly classify the total substitution into two components: interfuel substitution and factor substitution. Also, these substitutions are implicit in the level of aggregation of final demand as well as explicit and modeled through assumption of perfect complementarity, an econometric representation, or an engineering representation.

Dynamics. Classification of the dynamic behavior in the models parallels the classification for the producing sector. Thus, one looks for either myopic or clairvoyant interaction of variables, and instantaneous or gradual adjustment in the profiles of demands for goods and services brought about by changes in their relative scarcities or prices.

Trends. Whether due to government regulation, evolving tastes, or other unspecified factors, all the models recognize the existence of important demand changes that are essentially exogenous to the model structure. For example, the basic MRG assumptions include an eventual 10% reduction in energy demand through non-price-induced conservation, possibly as the result of standards being imposed by the government. Thus, it is possible to define a standard set of exogenous trends in specification of time profiles of exogenous government expenditures and exports, and non-price-induced conservation of energy demand.

Balancing Mechanism

The structure of the models' view of the balance between supply and demand is a source of major difference in the systems. All of the models preserve a physical balance in terms of the real flows of products and resources and, for models with explicit markets, a balance of monetary flows is maintained. However, the behavioral balance of the systems is a source of model diversity, of which the most important features can be described in terms of the model objective and treatment of dynamics.

Objective. The models are either positive or normative.

- Positive models postulate the existence of certain behavior on the part of consumers (e.g., maximizing utility) and the producers (e.g., maximizing profits) and assume that these sectors communicate through competitive markets. The primary focus of information exchange in the markets is the distribution of relative prices of the products and resources. For given prices, the behavioral assumptions plus a balancing of incomes yield the corresponding supplies and demands for resources and products. For the positive models, balance is achieved when these quantities and prices are equal. The system is then said to be in a market equilibrium.
- Normative models here start from the same technological description of production and consumption possibilities, but assume that the producing and consuming sectors operate cooperatively to maximize some joint criterion function. The system is in balance when the physical flows match and the production-consumption activities are at levels which maximize the criterion function over the feasible values.

Dynamics. The dynamics of the balancing mechanism cannot be viewed independently. Rather, its nature depends upon the treatment of the dynamics of production and consumption in a particular model. If the implementation of the dynamics of production and consumption is myopic, then the determination of the market equilibrium also is myopic. The positive models participating in the EMF study have followed this approach. However, such myopic characterization is not essential. It is possible to define a market equilibrium in the presence of perfect foresight, and thus have a clairvoyant implementation of the market equilibrium.

The only normative model in the EMF study (PILOT) optimizes the system simultaneously over the full period of study. It is clairvoyant. Hence, the decisions in any period affect and are affected by the decisions in every other period. The model anticipates future resource scarcity and adjusts current consumption and production activities to achieve the total system balance and maximize the overall criterion function.

MODEL COMPARISON

The application of the general framework permits a simple characterization of the main features of the alternate models. This section summarizes these model features for each system.

Hudson-Jorgenson Model [1, 2]

Producers:

Aggregation. The production sector utilizes a nine sector input-output accounting framework with five energy sectors and four nonenergy sectors. Capital and labor are treated as homogeneous quantities along with energy and materials in a production function for each sector. The aggregate energy and material inputs for each sector are further segregated into separate production functions for the five energy inputs and the four material inputs respectively. Hence, there is a hierarchical structure of 27 production functions which combine to provide implicitly the nine production functions in terms of the nine products.

Substitution. Interfuel substitution across the five macroenergy sectors and factor substitution across labor, capital, material, and energy are modeled explicitly using econometric relationships. Intrafactor perfect substitutability among types of capital and among types of labor is implicit in the assumption of homogeneous capital and labor.

Dynamics. The interaction of variables is myopic. Thus, prices and quantities determined in the production process depend only on the current period. The link over time, beyond exogenous trends, is found in the transfer of aggregate capital services. To the extent that capital services adjust gradually over time, the response of the production sector is gradual. However, the response of the production sector to price changes is instantaneous.

Trends. The model employs trends of the standard set of variables of population and labor productivity.

Consumers:

Aggregation. The nine sector accounting of the production sector is repeated in the final demand categories, which are further separated into consumption, investment, government expenditures, exports, and imports. However, in computing the tradeoffs between consumption and investment, or labor and leisure, the nine sectors are aggregated to one, with rules to insure consistency of values and prices. The disaggregation of quantities is through fixed shares for investment, government, imports, and exports. A series of behavioral relations with nonzero price elasticities is used for the disaggregation of consumption into the nine sectors.

Substitution. Substitution using econometric relationships occurs at the aggregate level between consumption and investment, and between labor and leisure. Given the aggregate values, there is no substitution across the nine sectors for investment goods, government expenditures, exports, or imports. For consumption, however, some substitution across energy and materials is included via econometrically estimated constant elasticity price effects. Also, an econometric representation of interfuel substitution is included in the model.

Dynamics. The behavioral relations governing the tradeoffs between aggregate consumption and investment are based on a formulation implying optimization over time. Through simplifying assumptions, this is implemented as a series of myopic calculations. Thus, the determination of consumption also is myopic and depends only on the corresponding prices and quantities in the current period.

Trends. The model assumes the standard set of trends for government expenditures and exports.

Balance:

Objective. The producers and consumers interact in markets where prices and quantities are in equilibrium. Producers demand capital services and labor which are obtained from consumers. Conversely, consumers demand consumption goods and leisure. Hence, capital formation and labor participation are determined endogenously. In each market, equilibrium is determined through the behavioral equations when the supply-demand prices and quantities for all transactions are equal.

Dynamics. The balance is determined sequentially in each period with the available homogeneous capital services operating as the dynamic link. Hence, separately for each period, the model determines a general market equilibrium in all markets.

Hnyilicza Model [3]

This model is closely related to the structure of the Hudson-Jorgenson model but it contains some very significant differences.

Producers:

Aggregation. There are two producing sectors in this highly aggregated model--energy and nonenergy. Each sector output is a function of five inputs--capital, labor, energy, nonenergy, and imports.

Substitution. Substitution across inputs of factors, energy and nonenergy materials and imports is explicitly modeled using econometric relationships. The cost function describes this substitution across various inputs as a function of prices of inputs as well as levels of output. Intrafactor perfect substitutability is implicit in the assumption of homogeneity implied by the aggregation into one type of labor (energy and nonenergy each) and two types of capital stocks (energy and nonenergy).

Dynamics. Interaction of variables is myopic. The only link over time beyond exogenous trends is found in transfer of capital stock for each of the two sectors. To the extent that capital services adjust gradually over time, the response of the production sector is gradual. However, the response of other inputs for production to price changes is instantaneous.

Trends. The model employs the standard set of variables of population, labor force, and labor productivity. Additionally, capital productivity trend is assumed.

Consumers:

Aggregation. The two sector accounting of the production sector is repeated. However, nonenergy consumption is disaggregated into consumption goods and capital services.

Substitution. Substitution across energy goods, nonenergy consumption goods, and nonenergy capital services is modeled explicitly through econometric relationships. Perfect interfuel substitution is implicit in the assumption of single energy form. Perfect substitution also is implicit in the components of the other aggregates of nonenergy consumption goods and nonenergy capital services.

Dynamics. Interaction of consumption variables is myopic with instantaneous adjustment of variables to price changes. The main intertemporal link is the relation describing the tradeoff between aggregate consumption and investment.

Balance:

Objective. Balance between supply and demand of various quantities is achieved through sequential computation of equilibrium for each period.

Dynamics. Sector specific capital stock is the main dynamic link.

Kennedy-Niemeyer Model [4]

This model also closely resembles the Hudson-Jorgenson accounting framework but utilizes very different behavioral assumptions.

Producers:

Aggregation. The production sector utilizes a nine sector input-output accounting framework with five energy sectors and four nonenergy sectors. Capital services are identified separately for each sector. There is a production function of each sector which is determined by inputs of capital and labor. A notable characteristic of the production functions for oil and gas concerns inclusion of an efficiency parameter to model resource depletion. Here, for the same level of other inputs, the output of oil (or gas) is a declining function of the cumulative oil (or gas) production.

Substitution. There is substitution between capital and labor for each producing sector, but no other form of substitution is included. In particular, the nine sector input-output coefficients are fixed and energy demand is proportional to output. Intrafactor perfect substitutability is implicit in the assumption of homogeneous labor. Also the components of each of the nine macrosectors are implicitly assumed to be perfect substitutes.

Dynamics. Similar to the Hudson-Jorgenson model, the interaction of variables is myopic. The nonmalleable capital services provide the main dynamic link. Additionally, resource depletion is modeled through changing scale parameters in the production functions.

Consumers:

Aggregation. As in the Hudson-Jorgenson system, this nine sector accounting of the production sector is repeated in the final demand categories.

Substitution. There is no substitution in the model in terms of final demand or the tradeoff between consumption and investment. Given the aggregate level of GNP, the allocation of output to the sectors and all components of final demand is determined according to fixed shares.

Dynamics. As in the Hudson-Jorgenson model, the determination of aggregate consumption and investment is based on a formulation implying optimization over time. Through simplifying assumptions, the implementation is achieved through a series of myopic calculations.

Trends. The model assumes the standard set of trends for government expenditures and exports.

Balance:

Objective. Balance between supply and demand of various quantities is achieved through sequential computation of an equilibrium for each period.

Dynamics. Sector specific capital stock and oil and gas production functions that include an efficiency parameter to model depletion provide the intertemporal linkage.

Wharton Annual Energy Model [5]

The Wharton model is a highly disaggregated system evolving from the large Wharton EFA annual and interindustry system.

Producers:

Aggregation. The model incorporates 59 industrial output sectors of which eight are energy producing sectors and the remainder produce various nonenergy goods and services. Separate production functions are estimated for each sector using a two level hierarchy in which, for each sector, Cobb-Douglas production function is used to determine value added from inputs of labor and capital services, and a constant elasticity of substitution, multivariable production function to determine aggregate level of intermediate inputs as a function of the vector intermediate inputs, and a final production function assuming perfect complementarity between value added and aggregate intermediate inputs to determine the sectoral output.

Substitution. Interfuel substitution across energy sectors, factor substitution across labor and capital, and substitution across intermediate inputs is modeled through econometric relationships using the mathematical structure outlined above. Intrafactor perfect substitutability is implicit in the assumption of homogeneous capital and labor. No direct substitution between material and factor inputs is included. By changing the mix of sector outputs, however, indirect substitution between materials and other factors is included.

Dynamics. The variable input-output coefficients are determined in the long run by the prices of all factor inputs. However, the adjustment to the long run values is not instantaneous. As implemented, in any period the coefficients depend on current and previous period prices and the rate of adaptation is determined by a separate lag parameter.

Trends. The model employs trends of the standard set of variables of population, labor force, and labor productivity.

Consumers:

Aggregation. Final demand is decomposed into consumption (14 categories), investment (32 categories), inventories, trade (14 categories), and government (6 categories). Behavioral equations for each of these categories are included in the macroeconomic model. Each category then is disaggregated in turn into the 59 sectors of the interindustry classification through the application of fixed shares.

Substitution. Substitution using econometric relationships occurs in all final demand categories at an appropriate level of aggregation noted above. These substitutions are a major source of potential variability in total energy use across major categories by final demand. Due to the extensive detail, the effect of substitution assumptions implicit in the level of aggregation is minimal.

Dynamics. The consumption equations operate on lagged prices and quantities which replicate a gradual adjustment to long run equilibrium. There is a separate parameter controlling the speed of adjustment for each final demand category weighted by the price and quantity differences in the previous period. No direct consideration of future prices is included.

Trends. A time profile of exogenous aggregate government expenditures is assumed.

Balance:

Objective. Long run equilibrium at full employment is a target for the model subject to the constraints implied by the dynamics of the short and long run adjustments. There is full short run equilibrium in the product markets in terms of prices and quantities. However, there is some uncertainty as to what extent the interindustry demands for capital and labor inputs are balanced with the prices and supply determined in the macroeconomic model of consumption-investment or employment-unemployment.

Dynamics. The model does not consider future prices as relevant to the decisions in any period. Therefore, the solution implementation is sequential, computing a short run equilibrium in each period. Due to the consideration of past prices and quantities, neither full employment nor long run equilibrium is achieved in any period. Rather, these serve as targets which the model approaches gradually.

PILOT Model [6, 7]

The PILOT model is a disaggregated system including a detailed process description of the energy sector. A main distinction compared to the other EMF systems is its normative approach to intertemporal tradeoffs and capacity limitations of the energy sector.

Producers:

Aggregation. The model incorporates 23 industrial sectors of which five deal with energy production. The energy sectors are further disaggregated into explicit process models for approximately 18 energy activities. Depletion of oil, gas, and natural uranium resources is modeled explicitly through engineering relationships describing progressively rising costs as functions of cumulative extraction. Labor input is considered a homogeneous quantity. However, nonhomogeneous capital inputs, represented as capacity measures for each sector, are separated for 18 nonenergy sectors and individual energy processes with explicit accounting of intertemporal interactions of the capacity formation.

Substitution. Substitution across energy inputs in the energy sector is modeled using engineering relationships. However assumption of perfect complementarity is made with respect to nonenergy inputs into energy production and all inputs into nonenergy production. Also perfect complementarity across components of each of 23 sectors is implicit in the definition of aggregates.

Dynamics. Interaction of variables is clairvoyant with current decisions determined by parameter values of all time periods. Due to fixed coefficients in the nonenergy production, no adjustment is possible in relative amounts of capital, labor, and material inputs. On the other hand, gradual adjustment in the inputs for energy production occurs in the detailed energy sector through capital requirements, new technology introduction dates, etc. Intertemporal linkage is provided through nonhomogeneous capital stocks and remaining energy resources.

Trends. The model employs trends of the standard set of variables of population, labor force, and labor productivity.

Consumers:

Aggregation. The 23 sector classification is repeated for consumption, investment, government expenditures, and net exports. Decisions on consumption are aggregated into a single value of aggregate consumption. The 23 sector composition of aggregate consumption is determined by the level of consumption or income.

Substitution. For a given level of consumption, the model uses a fixed shares system in any period, except for exports. Hence, there is no substitution other than through exports. Independent demand curves for exports are included to produce revenue which is used to balance energy and nonenergy imports. Any combination of exports that can be produced in excess of domestic demands is permitted.

Dynamics. Consumption is not permitted to decline over time. Except for this constraint, choices on the demand side are made taking explicitly into account the temporal availability of supply and production capacity.

Trends. In accordance with EMF scenario definitions, the model assumes eventual 10% reduction in energy demand through non-price-induced conservation.

Balance:

Objective. The distinctive characteristic of PILOT is the objective of determining the maximum cumulative consumption permitted by the physical capacities of the economy. Except for exports, no behavioral relations for conventional market equilibria are postulated. The system is distinctly normative.

Dynamics. The implementation of the maximization is achieved through simultaneous solution of the optimal consumption-investment problem for all periods. Hence future availabilities and decisions are as important as past decisions in determining the balance in any period. The system anticipates resource depletion and factor scarcity, adjusting consumption and investment to permit maximum aggregate growth in the face of these constraints. For this reason, the resulting pattern of investment may be of particular interest.

DRI-Brookhaven Model [8]

The implementation of this linked system is achieved through information transfers for three target years of 1985, 1990, and 2000 between the Hudson-Jorgenson (DRI) model, and the combined Input-Output-BESOM model of the Brookhaven National Laboratory. The Hudson-Jorgenson model described earlier is used as an intertemporal integrating device with the static I/O-BESOM model providing energy technology detail for the three target years. The information of aggregate energy demands for three target years at five sector detail is transmitted from the Hudson-Jorgenson model to the I/O-BESOM model. The detailed I/O-BESOM model in turn determines the relative prices, the fuel mix, and the capital requirements for energy taking into account the availability of new energy technologies and interfuel substitution by the producers and the consumers. The implementation of the interfuel substitution is achieved through an eight order disaggregation of the end use categories (such as space heat, process heat, petrochemical feedstocks, motive power, etc.). While the I/O-BESOM model's computer implementation for these target years is independent, separate numerical checks are made to assure intertemporal consistency of energy conversion and end use capacities.

Since the Hudson-Jorgenson subsystem possesses the characteristics of their model described earlier in this paper, they will not be repeated here. We briefly note, however, that the industrial sectors are disaggregated into nine sectors with five sectors for energy production. The labor and capital are treated as homogeneous quantities and the main dynamic link is provided through capital services. The market equilibrium is myopically determined for each period through behavioral equations for production and consumption. The characteristics of I/O-BESOM subsystem are described below.

Producers:

Aggregation. The production is further disaggregated into 110 input-output matrix and 30 energy production activities.

Substitution. The substitution across energy processes is considered by the BESOM subsystem. The input-output matrix is a fixed coefficient system, however.

Dynamics. The intertemporal linkage is provided by the Hudson-Jorgenson subsystem.

Trends. The technical coefficients are time trended in I/O-BESOM subsystem.

Consumers:

Aggregation. The I/O-BESOM subsystem considers the energy demands in terms of eight end use categories and nonenergy demands in terms of 90 industrial sectors.

Substitution. The I/O-BESOM subsystem considers a full range of substitution possibilities for eight energy end use categories. The nonenergy portion of I/O-BESOM is a fixed coefficient system, however.

Dynamics. Provided by the Hudson-Jorgenson subsystem.

Balance:

Objective. The cost minimization objective is used to achieve a supply-demand balance in the energy system consistent with the capacity limitations and the final demands for the nonenergy sectors, and limitations on aggregate levels of pollutant emissions due to energy production.

Dynamics. Provided by the Hudson-Jorgenson subsystem.

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Table D-1

MODEL COMPARISON

Feature / Model	Producers/Consumers				Balance	
	Aggregation	Substitution	Dynamics	Exogenous Trends	Objective	Dynamics
Hudson-Jorgenson 1975-2000	- 9 sectors with production function hierarchy - Malleable labor and capital - Consumption-investment at one sector level	- Price variable I-O coefficients - Consumption vs investment - Labor vs leisure - Price elastic demand - Varying elasticity of substitution for energy	- Separable given capital services in each period - Future price not considered - Capital accumulation main dynamic link	- Neutral technological change - Population, labor force	- Full employment - Market equilibrium for factors and products	- Instantaneous long run adjustment - Myopic equilibrium - Sequential solution
Hnyilicza 1975-2010	- 2 sectors without production function hierarchy - Malleable labor but nonmalleable capital	Same as H-J except I-O coefficients depend also on output levels	Same as H-J	- Factor specific technological change - Population, labor force	Same as H-J	Same as H-J
Kennedy-Niemeyer 1971-2010	- 9 sectors without production function hierarchy - Separate capital for each sector	- Capital-labor substitution in each sector production function - Fixed coefficients for I-O structure - Fixed shares for consumption	Same as H-J	- Neutral technological change - Population, labor force	Same as H-J	Same as H-J
Wharton 1975-1990	- 59 sectors - 14 consumption categories - 32 investment categories - 14 trade categories - 6 government categories - Implicit production function for each sector	Same as H-J except for constant elasticity of substitution for energy - Work under way to include process models to capture major energy substitutions.	- I-O coefficients determinably current and lagged prices and quantities - Lag determines gradual adjustment to long run equilibrium - Consumption determined by lagged prices and quantities		- Long run full employment target approached by simulation - Market equilibrium for all products and prices - Possible simulation equilibrium for factor requirements and prices (?)	- Gradual adjustment to long run equilibrium - Markets consider current and past prices - Sequential solution

Table D-1

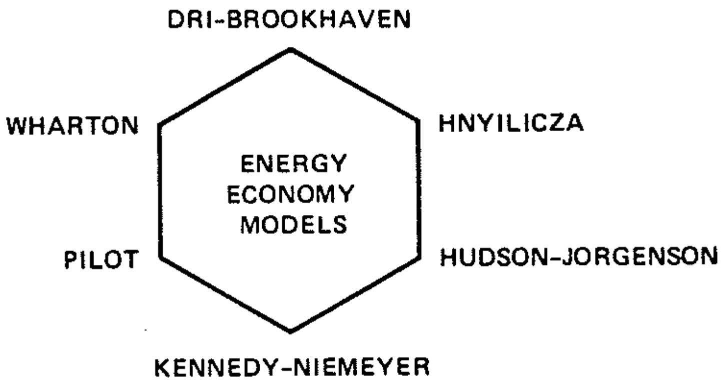
MODEL COMPARISON (continued)

Feature / Model		Producers/Consumers				Balance	
		Aggregation	Substitution	Dynamics	Exogenous Trends	Objective	Dynamics
PILOT 1973-2012		- 23 interindustry sectors - Disaggregated process models for energy production involving 18 processes	- Substitution in the production of alternate energy forms - Fixed coefficient for energy inputs to production process - Composition of aggregate demand varies with consumption level but not prices - Exports can provide a mix of output changes in the trade balance	- Periods linked via capital formation and capacities - Energy sector explicitly includes resource depletion - Consumption constrained not to drop over time	- Neutral technological change - Population, labor force	- Maximization of aggregate consumption subject to physical constraints - Except for exports, no behavioral links of prices and quantities	- Simultaneous solution of optimization problem. Hence, decisions in each period affect decisions in all other periods, past and future. - No discounting is included.
DRI-Brookhaven 1975-2000	All Years	Same as H-J	Same as H-J	Same as H-J	- Neutral technological change - Population, labor force	Same as H-J	Same as H-J
	For 1985, 1990 and 2000	- 110 interindustry sectors - Disaggregated process models for energy production involving 30 processes	- Substitution in production of alternate energy forms - Fixed coefficients for non-energy - Interfuel substitution for meeting fixed end use requirements		- Time trended technical coefficients	- Minimization of cost of meeting energy demands subject to pollutant emission constraints	

Appendix E

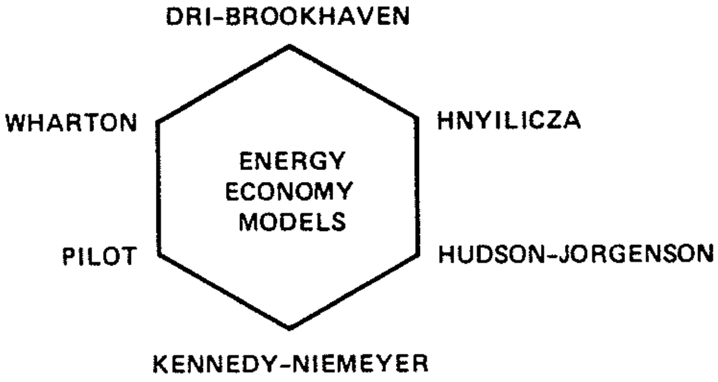
STRENGTHS AND LIMITATIONS OF THE MODELS: THE EMF PROCESS FROM A USER'S PERSPECTIVE

(forthcoming)



Appendix F

SCENARIO IMPLEMENTATIONS FOR THE PARTICIPATING EMF MODELS



SCENARIO IMPLEMENTATIONS FOR THE PARTICIPATING EMF MODELS

Working Paper

EMF 1.8

May 25, 1977

Energy Modeling Forum
Institute for Energy Studies
Stanford University
Stanford, California 94305

Appendix F

SCENARIO IMPLEMENTATIONS FOR THE PARTICIPATING EMF MODELS

Section 1

INTRODUCTION

This appendix is organized in five parts to present the assumptions defining the EMF scenarios and the results of the models' execution of these scenarios.

The second section contains a description of the driving variables and the record of their numerical values. The participating EMF models were designed originally for many different purposes. All the models can address many issues with varying degrees of approximation. To provide consistency for the analysis of the particular EMF issues, some standardization is necessary. The working group adopted a uniform set of assumptions to use in the execution of the EMF scenarios. Following the usage of the CONAES MRG, the variables determined by these assumptions are referred to as the driving variables. The specification of the driving variables and their numerical values determine the common inputs to the models. But these assumptions do not constitute a forecast, or even a consensus expectation of the future. They simply ensure that the differences in the model results provide information on differences in the models, not variations in input data. The working group explicitly chose to resolve differences in opinion regarding input variables on the basis of convenience rather than on the merits of opposing views. This facilitated the EMF task, but the resulting input assumptions are not warranted as forecasts. In large measure the EMF working group adopted the convenient energy sector assumptions developed by the Modeling Resource Group of the coincident CONAES study. Separate assumptions for the driving variables of the economy are required because of the differences in the issues under investigation. The key economic variables include population, labor force, and labor productivity growth. Individual model deviations from these assumptions are indicated.

The third section of this appendix contains the definition of six scenarios originally designed for the EMF study. These scenarios are not intended to be forecasts. Rather, they are carefully designed perturbations of the base case intended to provide information on the sensitivity of the models' link between energy and the economy. The high growth case stimulates economic activity to illustrate the direct effect of the economy on energy demand. The energy constraint cases reduce energy availability or raise energy prices to measure the embedded substitution in the models. The declining oil import price case provides a symmetric test of the effect of lower energy prices. The case taxing delivered energy was intended to reveal the impacts of imposing energy price increases at different points in the energy system. None of the models, however, executed both scenario five and six and, therefore, the distinction is not maintained and only the fifth scenario is presented.

The fourth section tabulates the exceptions required by the modelers in adapting their systems to the common assumptions. These exceptions arise especially due to the differences in the model structures and levels of aggregation. These exceptions are a useful medium to convey some model differences. For example, the positive equilibrium models did not implement the energy quantity restrictions that are convenient in the normative or optimization models. Rather, the scarcity of energy is simulated by a combination of Btu taxes and income redistribution. The EMF working group attempted to minimize the number of exceptions but some significant differences remained. Generally, these do not affect the central results reported in Volume 1. In the one prominent instance where the result was sensitive, in the measurement of substitution effects in the Hudson-Jorgenson model, an ad hoc correction was used as discussed in the commentaries below.

The plots of some of the key variables and parameters for various model runs follow in the fifth section. This section also includes commentary providing definitions and explanations of the various graphs. The results of six models with five scenarios for a number of years and dozens of parameters produce a forbidding volume of output. All the results are presented later in tabular form, but the most interesting results are compared in the graphs. These graphs display a substantial amount of information in an easily understood format. Once again, however, the reader is cautioned that the results were developed for model comparisons only. The graphs do not constitute an EMF forecast.

The sixth section contains computer printouts of the model results. The EMF working group selected a few key variables that the modelers were asked to report. Each modeler did not report all details available in his model. Generally speaking, the models provided the information on all requested variables. The more aggregated models do not have the full detail, but provide the information at the appropriate level of aggregation.

Section 2

DRIVING VARIABLES

The driving variables provide a standard set of assumptions to all participating modelers to permit scenario runs on a common basis. These assumptions are reasonable but do not represent an EMF forecast. They are designed for sake of consistency of intermodel comparisons only.

TABLE F-1

```
-----------------------------------------------------------------------------------
I: EMF(1.2)                          DRIVING VARIABLES
-----------------------------------------------------------------------------------

                                                                          VARIABLE
                                                                           VALUES
                                                                          --------
A.  ENERGY SECTOR ASSUMPTIONS
-----------------------------

     SOURCE: NRG. ALL DOLLAR COSTS ARE SPECIFIED HERE IN 1975
             DOLLARS. BILL FINAN HAS INDICATED THAT MOST OF THE
             EMF MODELS OPERATE IN 1972 DOLLARS WHICH WOULD BE
             SUPERIOR FOR OUTPUT PRESENTATION. THIS WILL BE
             ADDRESSED IN A SEPARATE OUTPUT FORMAT DISCUSSION.


 1. GROWTH RATE OF REAL GROSS NATIONAL PRODUCT (GNP)
 ...................................................
     (% PER ANNUM)  THE VALUES INDICATED ARE NRG BASE CASE
     ASSUMPTIONS. THE EMF MODELS TREAT THIS COMPONENT
     ENDOGENOUSLY. HENCE, THESE DATA ARE PROVIDED FOR
     INFORMATION ONLY.
                                              1970-75                         2.00
                                              1975-80                         5.70*
                                              1980-90                         3.28
                                              1990-2000                       2.84
                                              2000-2010                       2.84
                                              2010 AND BEYOND                 1.80
                                     AVERAGE FOR 1975-2010                    3.40

     * IN ASSESSING THE REASONABLENESS OF THIS RELATIVELY HIGH
       INITIAL GNP GROWTH RATE PROJECTION, ONE MUST OBSERVE
       THAT THE AVERAGE ANNUAL GROWTH RATE OVER 1970-80 WOULD
       BE ONLY 3.8 %.


 2. CAPITAL COSTS OF ELECTRICITY GENERATING TECHNOLOGIES
 .......................................................
     $/KWE, IN YEAR 2000; ALL CAPITAL COSTS REPORTED AT 65 %
     CAPACITY FACTOR FOR BASE GENERATION; ALL CAPITAL COSTS
     FOR NUCLEAR REACTORS EXCLUDE THE COSTS OF INITIAL FUEL
     INVENTORIES. COSTS ARE INTENDED TO INCLUDE INTEREST
     DURING CONSTRUCTION.
   A. COAL-FIRED PLANT, INCLUDING SULFUR REMOVAL EQUIPMENT                    520
   B. LIGHT WATER REACTOR (LWR)                                               650*
   C. ADVANCED CONVERTER REACTOR (CONVERSION RATIO = 0.82)                    715*
   D. FAST BREEDER REACTOR (FBR)                                              810*
   E. SOLAR PRODUCED ELECTRICITY                                             1730

     *  REACTOR COSTS GIVEN ARE INDICATORS OF COST CHANGES IN
        OTHER ELEMENTS OF THE NUCLEAR FUEL CYCLE.
```

```
3. DIFFERENTIAL TECHNICAL CHANGE IN THE ENERGY SECTOR (% PER
   ANNUM) OVER THAT IN THE REST OF THE ECONOMY.                                  0

4. U.S. OIL AND GAS RESOURCES (10**15 BTU) AT COST OF $2.00
   PER MILLION BTU                                                            1720

5. ADDITIONAL U.S. URANIUM RESOURCES (CUMMULATIVE MILLION TONS
   OF U3O8) RECOVERABLE AT MINIMUM ACCEPTABLE PRICE* OF
   LESS THAN:
.....................................................................
                                                $   15 / LB               1.28
                                                $22.50 / LB               2.05
                                                $   45 / LB               3.70
                                                $   75 / LB               5.46
                                                $  125 / LB               7.80
                                                $  150 / LB               9.24
                                                $  225 / LB              12.57

      * THIS "MINIMUM ACCEPTABLE PRICE" IS 50 % HIGHER THAN THE
        "FORWARD COST" CONCEPT THAT IS CONVENTIONALLY USED IN
        ERDA DOCUMENTS.

6. EXTRACTION AND DELIVERY COSTS OF COAL
...............................................
        $ / MILLION BTU; 1985 AND BEYOND.
     A. LOW SULFUR COAL
        1. FOR UTILITIES (NATIONAL AVERAGE)                               1.13
        2. FOR SYNTHETIC FUELS (MOUNTAIN STATES)                          0.58

     B. HIGH SULFUR COAL
        1. FOR UTILITIES (NATIONAL AVERAGE)                               0.75
        2. FOR SYNTHETIC FUELS (MOUNTAIN STATES)                          0.48

7. TOTAL AVERAGE DELIVERED COST OF SYNTHETIC FUELS
.........................................................
        $ / MILLION BTU. AVAILABILITY DEFINED AS PRODUCTION
        CAPACITY OF  .5 X 10**15 BTU / YEAR.
     A. COAL GASIFICATION, AVAILABLE IN 1990                              3.70
     B. SHALE OIL OR COAL LIQUEFACTION, AVAILABLE IN 1995                 3.70

8. TOTAL AVERAGE COST OF CLEAN NONELECTRIC ALTERNATIVE ENERGY
   SYSTEMS (AES). ($ / MILLION BTU)                                       5.00
....................................................................
        INCLUDES BOTH CONSERVATION AND SUPPLY SYSTEM OPTIONS.
        E.G. SOLAR HEATING AND COOLING OF BUILDINGS, BIOMASS
        CONVERSION, IN SITE SHALE RETORTING, LARGE NEW PETROLEUM
        DISCOVERIES, ETC. INCLUDED AS A SAFETY DEVICE TO PREVENT
        ENERGY SECTORS FROM PROVIDING ERRATIC OUTPUTS. IT
        CREATES AN EFFECTIVE CEILING ON PRICES. FOR INCORPORATION
        IN INPUT/OUTPUT FRAMEWORKS, THE EMF AGREED TO TREAT
        THE AES AS A SOURCE OF DOMESTIC CRUDE OIL OR NATURAL
        GAS AT ASSUMED PRICES AT THE WELLHEAD.
```

Change
12/11/76

```
9. NONPRICE INDUCED CONSERVATION
.................................
      % REDUCTION IN DEMAND BELOW THAT PREDICTED AT ANY GIVEN
      PRICE AND INCOME IN THE INDIVIDUAL MODELS. HENCE, THIS IS
      AN ENERGY EFFICIENCY TREND IN THE CONSUMING SECTOR THAT
      IS INCREMENTED TO THE ENDOGENOUS EFFECTS EVIDENT IN THE
      HISTORICAL DATA.
      LINEAR INCREASE FROM 0 IN 1975 TO:        (IN 2010)              10

10. DISCOUNT RATES (% PER ANNUM)
.................................
      THIS ITEM IS ENDOGENOUS IN THE GROWTH MODELS AND SHOULD
      BE REPORTED. THESE ASSUMPTIONS ARE PROVIDED ONLY FOR
      THOSE MODELS REQUIRING EXOGENOUS INPUT.
    A. PRE-TAX (FOR USE IN PRICING AND INVESTMENT DECISIONS IN
       THE ENERGY SECTOR)                                            13.0
    B. POST-TAX (FOR USE IN DISCOUNTING BENEFITS OF ALTERNATIVE
       TECHNOLOGY OPTIONS)                                            6.0

11. QUANTITY CEILINGS AND PRICES OF IMPORTED OIL AND GAS
.........................................................
    A. ANNUAL IMPORT LIMIT, AS A PERCENTAGE OF ANNUAL DOMESTIC
       NATURAL AND SYNTHETIC OIL AND GAS CONSUMPTION.                 33*

    B. CUMMULATIVE IMPORT LIMIT (10**15 BTU).                        100*

    C. PRICE OF IMPORTED OIL, IN 1975 DOLLARS PER BBL,
       INCLUSIVE OF TARIFF                                           13.0*

      * THE EMF DECIDED NOT TO IMPOSE THESE LIMITS AND HAS
        AND HAS SEPARATE PRICING PATHS EXOGENOUSLY DETERMINED.


12. YEAR OF COMMERCIAL AVAILABILITY
...................................
      AT CUMMULATIVE INSTALLED CAPACITY OF 6 GWE
    A. ADVANCED CONVERTER REACTOR (CONVERSION RATIO = 0.82)          2[illegible]
    B. FAST BREEDER REACTOR (FBR)                                    20[illegible]
    C. SOLAR PRODUCED ELECTRICITY (AT CENTRAL VALUE CAPITAL COSTS)   2[illegible]

13. CEILING ON THE GROWTH RATE IN CAPACITY OF NEW TECHNOLOGIES
...............................................................
              40 % FOR FIRST  5 YEARS AFTER INITIAL AVAILABILITY
              30 % FOR SECOND 5 YEARS AFTER INITIAL AVAILABILITY
              20 % FOR THIRD  5 YEARS AFTER INITIAL AVAILABILITY
              10 % THEREAFTER
```

```
14. NUCLEAR MORATORIUM CONSTRAINTS (NOT APPLICABLE IN BASE CASE)
................................
        CONSTRUCTION OF ALL PLANTS WHICH ARE NOW MORE THAN 25 %
        COMPLETE. THESE PLANTS WILL BE COMPLETED IN 1983 AND
        RETIRED AT THE NORMAL RATE. NO NEW CAPACITY WILL COME
        ON LINE AFTER THAT DATE. (DATA FROM HOGAN MEMO 6/14/76)
        YEAR AND CAPACITY EXPECTED (VALUES IN GWE):
                                          1983                          70.

15. COAL LIMITS (NOT APPLICABLE IN BASE CASE)
...............
        A LOGISTIC CURVE STARTING IN 1975, WITH 40 QUADS PER YEAR
        IN 2000 AND ASYMPTOTIC TO 50 QUADS PER YEAR.
        Y = 50. / (1 + E**(.613-.088T) )  QUADS PER YEAR.
                                          1975                          15.40
                                          1985                          25.80
                                          2000                          40.00
                                          2010                          45.30
                                          2020                          47.90

16. SHALE LIMITS (NOT APPLICABLE IN BASE CASE)
................
        A LOGISTIC CURVE WITH 2 QUADS PER YEAR IN 2000.
        6 QUADS PER YEAR IN 2010. AND ASYMPTOTIC TO 12 QUADS
        PER YEAR.
        Y = 12 * (1 + E**(5.633 - .161T) )  QUADS PER YEAR.
                                          1975                          0.
                                          1985                          0.21
                                          2000                          2.00
                                          2010                          6.00
                                          2020                          10.00

17. PRICE CONTROLS
..................
        FOR THE EMF SIMULATIONS. PRICE CONTROLS ON NEW
        NATURAL GAS AND OIL ARE ASSUMED TO BE REMOVED BY 1979.
```

} CHANGE 12/11/76

```
18. EXOGENOUS NUCLEAR INTRODUCTION
..................................
        FOR EMF MODELS REQUIRING EXOGENOUS SPECIFICATION OF
        THE INTRODUCTION RATE OF NUCLEAR POWER. IT IS ASSUMED
        THAT 50 % OF NEW CAPACITY IS NUCLEAR.
```

} CHANGE 12/11/76

```
E.  ECONOMIC SECTOR ASSUMPTIONS
-------------------------------

 1. EXOGENOUS COMPONENTS OF FINAL DEMAND
 ......................................
         GOVERNMENT EXPENDITURES PROPORTIONAL TO GNP.
         EXPORTS PROPORTIONAL TO GNP IN MODELS
         REQUIRING EXOGENOUS ASSUMPTIONS.

 2. POPULATION AND LABOR FORCE
 ..............................
      A. CENSUS SERIES II PROJECTIONS.
         TOTAL POPULATION (IN THOUSANDS) LISTED BELOW BY 5-YEAR
         PERIOD:
                                       1975                          213.450
                                       1980                          222.769
                                       1985                          234.068
                                       1990                          245.075
                                       1995                          254.495
                                       2000                          262.494
                                       2005                          270.377
                                       2010                          278.754

      B. LABOR FORCE TAKEN FROM THE MONTHLY LABOR REVIEW, JULY 1973
         FOR DATA UP TO 1990. EXTRAPOLATION THEREAFTER BASED ON
         LABOR FORCE ASSUMED AT 46 % OF THE POPULATION. PROJECTIONS
         (IN THOUSANDS) LISTED BELOW BY 5-YEAR PERIOD:
                                       1975                           94.800
                                       1980                          101.900
                                       1985                          107.700
                                       1990                          112.600
                                       1995                          117.100
                                       2000                          120.800
                                       2005                          124.400
                                       2010                          128.200

 3. TECHNOLOGICAL CHANGE
 .......................
      A. ALL NON-ENERGY SECTORS
         LABOR AUGMENTING TECHNICAL PROGRESS SET AT 2 % PER YEAR.

      B. ENERGY SECTORS
         FOR MODELS WITHOUT PROCESS DETAIL, IMPUTE AGGREGATE
         TECHNOLOGICAL CHANGE IMPLIED BY NRG ASSUMPTIONS AND
         CONSISTENT WITH THE NON-ENERGY SECTOR CHANGES.
```

```
4. INFLATION AND UNEMPLOYMENT
.............................
      SOURCE: WHARTON THROUGH 1985. EXTRAPOLATION OF TRENDS
              THROUGH 1990; CONSTANT THEREAFTER.
   A. PER CENT CHANGE GNP DEFLATOR
                                    1976                                 5.3
                                    1977                                 6.7
                                    1978                                 6.2
                                    1979                                 5.8
                                    1980                                 4.5
                                    1981                                 4.1
                                    1982                                 4.3
                                    1983                                 3.9
                                    1984                                 3.2
                                    1985                                 3.5
                                    1986                                 3.1
                                    1987                                 3.1
                                    1988                                 3.1
                                    1989                                 4.1
                                    1990                                 4.5
                                    BEYOND 1990                          4.6

   B. UNEMPLOYMENT RATE
                                    1976                                 7.4
                                    1977                                 5.7
                                    1978                                 6.4
                                    1979                                 6.6
                                    1980                                 6.9
                                    1981                                 6.5
                                    1982                                 6.4
                                    1983                                 6.3
                                    1984                                 5.8
                                    1985                                 5.6
                                    1986                                 5.6
                                    1987                                 5.2
                                    1988                                 5.0
                                    1989                                 4.8
                                    1990                                 4.3
                                    BEYOND 1990                          4.3
5. MONETARY POLICY, TRANSFER PAYMENT, TAX POLICY
................................................
   A. MONETARY POLICY
     REQUIRED ONLY FOR WHARTON MODEL. TO BE SPECIFIED BY
     WHARTON AND MADE CONSISTENT WITH INFLATION AND UNEM-
     PLOYMENT ASSUMPTIONS.
   B. TAX POLICY, TRANSFER PAYMENTS
     STANDARDIZATION OF INPUT ASSUMPTIONS COMPLICATED BY
     DIVERSITY OF MODEL REPRESENTATIONS OF TAX STRUCTURE.
     IMPACTS ON RESULTS CAN BE CHARACTERIZED THROUGH EX POST
     ANALYSIS OF AGGREGATE GOVERNMENT RECEIPTS, EXPENDITURES,
     AND DEFICITS. THESE SHOULD BE REPORTED BUT THE INDIVIDUAL
     MODELERS ARE ASKED TO SPECIFY A CONSISTENT NOMINAL CASE.
```

```
6. PHYSICAL DEPRECIATION RATES
...............................
       DEFINITION: USABLE LIFETIME
       SOURCE: ENERGY SECTOR: STANDARDIZE AT 30 YEARS.
               NON-ENERGY SECTOR:
                      A. EQUIPMENT YEARLY DETERIORATION (%)                     14.8
                      B. PLANT YEARLY DETERIORATION (%)                          5.86
                      C. HOUSING STOCK ANNUAL DETERIORATION (%)                  2.4
                      D. AVERAGE DEPRECIATION RATE* (%)                          9.25

        *  USING THE KUH AND SCHMALANSEE DEPRECIATION RATES(A,B,C) \
           WITH THE 1974 COMPOSITION OF FIXED INVESTMENT GIVES     |
           AN AVERAGE DEPRECIATION RATE OF 9.45 %. USING THE       |
           1968 - 1974 AVERAGE COMPOSITION OF THE CAPITAL STOCK     > *
           GIVES A FIGURE OF 9.25 %. THIS IS ESSENTIALLY DUE TO    |
           THE UNDERREPRESENTATION OF RESIDENTIAL STRUCTURES IN    |
           THE RECESSION OF 1974. KENNEDY RECOMMENDS USE OF        |
           THE 9.25 % RATE. (REFERENCE KENNEDY LETTER OF 12/16/76) /

7. NON-ENERGY IMPORT/EXPORT PRICE ASSUMPTIONS
................................................
       FOR MODELS REQUIRING EXOGENOUS ASSUMPTIONS, INCREASE
       NOMINAL PRICE AT RATE OF INFLATION SPECIFIED IN ITEM 4.

8. INITIAL VALUES OF CAPITAL, GOVERNMENT DEBT, FOREIGN DEBT
..............................................................
       LEFT TO INDIVIDUAL MODELS TO AVOID DIFFICULTY OF
       ESTABLISHING AN ARBITRARY BASE YEAR. ASSUME STANDARD
       GOVERNMENT DATA USED TO INSURE CONSISTENCY. THE DEFINI-
       TIONS AND VALUES SHOULD BE AVAILABLE FOR COMPARISON
       ACROSS MODELS.

9. TIME FRAME
..............
       THE TIME FRAME OF SIMULATION WILL VARY BY MODEL. THE
       LONGER THE PERIOD THE MODEL CAN BE RUN FOR, THE BETTER.
       AN ARBITRARY CUTOFF OF 2020 CAN BE USED.
```

---

[*] These results are derived with an error in the choice of weights. This was discovered after the modelers noted exceptions and their own deviations from this assumption. The corrected figure is closer to 5.9%.

Section 3

SCENARIO DEFINITIONS

Through scenarios, the EMF working group implemented a set of carefully designed perturbations from a base case to obtain information on model responses with regard to the link between energy and the economy. The main assumptions of these scenarios are presented here.

TABLE F-2

```
------------------------------------------------------------------------
II: EMF(1.2)              SCENARIOS FOR EMF MODEL EXECUTION
------------------------------------------------------------------------

1. BASE CASE
............
   COMMENTS: ALL BASE ASSUMPTIONS FOR EXOGENOUS PARAMETERS.
     A. OIL IMPORT PRICE AT $13.00 IN 1975 AND INCREASING
        BY 2% / YEAR IN REAL TERMS.
     B. NO QUANTITY RESTRICTIONS ON IMPORTS.
     C. NO PRICE CONTROLS ON DOMESTIC PRODUCTION

2. DECLINING OIL IMPORT PRICE
..............................
   COMMENTS: BASE CASE WITH THE FOLLOWING EXCEPTIONS
     A. OIL IMPORT PRICE FALLING BY 2% / YEAR THROUGH 1990
     B. OIL IMPORT PRICE RISING  BY 2% / YEAR AFTER 1990

3. HIGH GROWTH CASE
...................
   COMMENTS: BASE CASE WITH THE FOLLOWING EXCEPTIONS
     A. SERIES I CENSUS PROJECTIONS OF POPULATION
     B. TECHNOLOGICAL CHANGE IN NON-ENERGY SECTORS (+.5%/YR)
   COMMENTS: THE PURPOSE OF THIS CASE IS TO PRODUCE AN            GROWTH RATE
             AGGREGATE INCREASE IN GNP OVER THE BASE CASE OF
             1 % A YEAR. THIS WILL DISPLAY THE IMPLIED
             INCOME ELASTICITIES OF THE MODELS AND PROVIDE
             A HIGH DEMAND CASE THAT WILL BE MORE VULNERABLE
             TO ENERGY CONSTRAINTS.

4. HIGH GROWTH WITH ENERGY CONSTRAINTS*
.......................................
   COMMENTS: HIGH GROWTH CASE WITH THE FOLLOWING EXCEPTIONS
     A. MRG CONSTRAINTS ON NUCLEAR, COAL, AND SHALE
     B. OIL AND GAS IMPORTS AT MOST TEN MILLION BARRELS / DAY
     C. NONELECTRIC AES AT $ 8.00 PER MILLION BTU. THIS
        RAISES THE EFFECTIVE CEILING ON ENERGY PRICES.

5. BASE CASE WITH ENERGY CONSTRAINTS*
.....................................
   COMMENTS: BASE CASE WITH THE FOLLOWING EXCEPTIONS
     A. MRG CONSTRAINTS ON NUCLEAR, COAL, AND SHALE
     B. OIL IMPORTS AT MOST TEN MILLION BARRELS / DAY
     C. NONELECTRIC AES AT $ 8.00 PER MILLION BTU. THIS
        RAISES THE EFFECTIVE CAILING ON ENERGY PRICES.
```

```
6. BASE CASE WITH BTU TAX
.........................
     COMMENTS: BASE CASE WITH THE FOLLOWING EXCEPTIONS
       A. $1.00 / MILLION BTU  TAX ON ALL DELIVERED ENERGY
          EXCEPTING SOLAR ENERGY.
       B. REVENUE RETURNED VIA TAX REDUCTION

     * THE ENERGY CONSTRAINTS ARE THE COAL, NUCLEAR, AND SHALE
       LIMITS FROM THE MRG ASSUMPTIONS OVER A PLANNING HORIZON
       OF 1976 - 2020. THE PURPOSE OF THESE SCENARIOS IS TO
       SEVERELY RESTRICT SUPPLY, WITHOUT FUEL SUBSTITUTION,
       AND THEREBY RAISE THE AVERAGE PRICE OF ALL ENERGY. PRICES
       RISE BY A FACTOR OF 4 OR MORE IN MRG TESTS OF THESE
       CONSTRAINTS. FOR MODELS WITHOUT A DETAILED SUPPLY SIDE OR
       A LONG PLANNING HORIZON, THE SCARCITY RENTS WILL NOT BE
       RECOGNIZED. TO PRESERVE THE INTENT OF THESE SCENARIOS,
       SOME PROXY FOR THE SCARCITY RENTS MUST BE INCLUDED.
       THIS FOURFOLD INCREASE IN ENERGY PRICES BY 2010 SHOULD
       GUIDE THE IMPLEMENTATION OF THE ENERGY CONSTRAINT CASES.
-----------------------------------------------------------------------------
```

Ultimately combined with Scenario 5.

Section 4

MODEL EXCEPTIONS

All models could not implement all the assumptions as specified by the EMF working group. This section contains the exceptions made by the modelers in implementing the scenarios.

In Table F-3, page F-16, the first column lists the serial number of the assumption or the scenario, the detailed specification of which can be found in Sections 2 or 3. The remaining columns list the exceptions for each model.

EXCEPTIONS OF PARTICULAR RELEVANCE TO THE EMF STUDY

The deviations of the particular models from the central assumptions of the EMF study often are matters of convenience and have little impact on the main conclusions of the study. There are some model exceptions, however, which must be recognized if the results are to be interpreted properly. For example, a variety of model limitations or modelers' preferences leads to a lack of uniformity in the magnitude of the energy taxes or energy restrictions which are so central in the evaluation of substitution potential. The only meaningful cross-model comparison in this regard, therefore, is the abstract derivative concept of the elasticity of substitution. While this may be appropriate to the modeler, it is not as meaningful as the percent reduction in GNP for a given reduction in energy, a comparison which can be inferred but has not been tested here. This section summarizes the most important exceptions judged to be of particular relevance to this study.

Pilot Model

In contrast to the other models, this system is designed to impose direct restrictions on the supply of energy. But, not using a price oriented market structure, the model cannot impose taxes. This precluded the execution of Scenario 6, which was dropped later in any event. The chief development effort, stimulated by EMF interaction, is the insertion of substitution possibilities in the choices of consumers and producers for energy utilization.

Table F-3: MODEL EXCEPTIONS   DRIVING VARIABLES: ASSUMPTIONS A.1-A.6

Assumptions	#1 PILOT	#2 Kennedy-Niemeyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
A.1	Did not require. →				
A.2		Did not need items C through E; only one nuclear process.	No nuclear sector or solar in the model.	(From BNL)	Not implemented.
A.3			Not applicable.	1971-1985: -0.11% 1985-1990: -0.79% 1990-2000: -1.65%	
A.4	Uses endogenous physical supply curve through finding rate functions.		Not applicable.	Implemented through linkage with Brookhaven-Illinois model.	Not implemented.
A.5		Used constant price of $30/lb.	No nuclear sector in the model as implemented for EMF.	- " -	- " -
A.6	Two coal types: Western and Eastern. No further disaggregation in the model as implemented for EMF.	Single coal type.	Single coal type.	- " -	- " -

DRIVING VARIABLES: ASSUMPTIONS A.7-A.12

Assumptions	#1 PILOT	#2 Kennedy-Niemeyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
A.7		No synfuels in the model.	No synfuels in the model.	Implemented through linkage with the Brookhaven-Illinois model.	Not implemented.
A.8			AES not used.	AES not used.	AES not used.
A.9		Did not implement; used fixed consumption ratios.	Did not implement.	Zero.	
A.10	Used zero discount rate to discount future consumption.	Average Real rate of return, relative to 1972 can be read off computer output (9+ goes up at first since domestic oil and gas returns are averaged in; goes down later due to generally worsening of income/capita as a result of higher costs).	Do not require.	Endogenous and estimated implicitly in the model of household behavior.	
A.11	Not implemented by EMF decision.				
A.12		Not implemented.	Not implemented. Beyond the planning horizon of the model.	Implemented through linkage with the Brookhaven-Illinois model.	Not implemented.

DRIVING VARIABLES: ASSUMPTIONS A.13-A.18

Assumptions	#1 PILOT	#2 Kennedy-Niemeyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
A.13		Not implemented but not needed.	Not implemented. Beyond the planning horizon of the model.	Implemented through linkage with the Brookhaven-Illinois model.	Not implemented.
A.14	Not applicable in Base Case. →	→	→	→	→
A.15	Not applicable in Base Case. →	→	→	→	→
A.16	Not applicable in Base Case.	No shale. →	→	→	→
A.17	No price controls assumed.	No price controls assumed.	No deviation.	No price controls assumed.	
A.18		Okay (we actually did use this).	No nuclear in the model.	(From BNL.)	Not required.

DRIVING VARIABLES: ASSUMPTIONS B.1-B.6

Assumptions	#1 PILOT	#2 Kennedy-Niemeyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
B.1	Government proportional to consumption; Exports are endogenous.		Exports are endogenous.	Government and exports proportional to GNP.	
B.2				Census Series II projections.	
B.3			Did not require.	Aggregate input-to-output productivity increases at 1.15% per year.	
B.4	Did not require.	Did not require	Endogenous treatment of inflation and unemployment.	Inflation, % per year: 1971-1985: 5.14 1985-1990: 3.76 1990-2000: 3.84	
B.5	Did not require.	Did not require.		Did not require.	Did not require.
B.6	Used a depreciation rate of 4.4%.		Used different depreciation rates by sector.	Depreciation of capital: 6.2%	

DRIVING VARIABLES: ASSUMPTIONS B.7-B.9

Assumptions	#1 PILOT	#2 Kennedy-Niemeyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
B.7	Did not require.	Did not need.	Import prices are exogenous; Export prices are endogenous.	Nonenergy import prices increase at the inflation rate specified in Item B.4.	
B.8		1) Needed to calibrate model. 2)-3) Not needed.		1973 value of ($ 1958 x 10^9) Capital 1991.2 Net private domestic claims on Gov't 428.2 Net claims on the rest of the world 44.97	
B.9	1973-2012	1971-2010	1975-1990	1975-2000	

SCENARIOS

	#1 PILOT	#2 Kennedy-Niemyer	#3 Wharton	#4,6 Hudson-Jorgenson & DRI-Brookhaven	#5 Hnyilicza
1				The Base Case used was based on macroeconomic developments comparable with the DRI TRENDLINE 876 forecast and on energy developments based on ERDA/BNL forecast No.2.	
2				Implemented through changed energy import prices.	
3			Implemented through balanced increase in government expenditures and decrease in corporate and personal income tax rates.	Real GNP growth increased by 1% per annum through increased rate of aggregate input-to-output productivity.	
4		AES included as inputs.	Implemented through higher energy prices by imposition of Btu tax.	Implemented through higher energy prices by imposition of Btu tax.	Implemented through higher energy prices by imposition of Btu tax.
5			– " –	Did not run.	– " –
6	Did not implement.	Did not implement.			

Kennedy-Niemeyer Model

In principle, this model can impose direct restrictions on the amount of energy used. Originally, this seemed equivalent to the imposition of a Btu tax. But, because there is no substitution allowed in the model, the duality between taxes and energy restrictions does not apply. The tax, therefore, produces a small reduction in income and a small reduction in energy demand. A direct restriction in energy use would have a larger impact in this model. In addition, the assumption of a fixed saving rate in the model removes one link in the chain between the availability of energy and capital investment. The fixed savings rate reduces the impact of energy scarcity when compared to the assumption of a fixed rate of return on capital. As this model is intended to show the greatest impact of energy scarcity, the modelers are undertaking modifications to accommodate this new insight.

Wharton Model

The complexity of this system evolved to examine a range of shorter run macroeconomic issues. The extensions to energy detail were under way at the time of the EMF study and this prevented full implementation of all the scenario detail. In particular, the model was run only through 1990. And large changes in the input variables for higher economic growth or stiff energy taxes could not be accommodated. Large changes in these variables tend to upset the financial and employment components of the model in unexpected degree and the modelers chose not to apply the system outside the range of its design. The relatively small changes produce instability in the estimation of some of the comparative parameters, such as the implicit income elasticity. Without a specific supply sector, the model cannot constrain energy input and produces no estimate of energy imports. These latter characteristics change in the version of the model under development. The chief extension is the further disaggregation of the energy sector and the inclusion of specific process models.

Hudson-Jorgenson Model

The restrictions in energy use were implemented with a Btu tax on delivered energy. This is primarily a matter of convenience to maintain compatibility with other applications of this model. There is no reason, in principle, why the model could not impose the tax on primary energy or impose a direct reduction in energy use and solve for the equivalent tax. The model structure and implementation are compatible with either test, but tax on delivered energy was chosen. This necessitated the ad hoc corrections of results explained in the commentary in Section 5 of this appendix.

Hnyilicza Model

The structure and implementation of this model are oriented towards price and tax tests rather than direct restrictions on energy quantities. Therefore the restriction on energy was implemented by imposing a Btu tax. In examining the results, the relatively low price of energy is noted. This feature is explained by the fact that in these implementations the historical rate of technological change in the energy sector is maintained. No depletion effects are included. The real costs of domestic energy, therefore, decline over time as domestic production expands. No imports are needed to meet the growing energy demands and the price of energy equilibrates at the low level predicted by a continuation of the preembargo trend.

DRI-Brookhaven Model

The chief role of this model is to improve the energy sector detail while preserving the aggregate substitutions of the Hudson-Jorgenson model. The comments for the latter system apply to this more detailed model as well.

Section 5

SUMMARY GRAPHS

The comparison of the results of the many model runs is facilitated by graphical presentation. This section presents these graphs with an associated commentary by way of a limited explanation. The models encompass far more detail than this study is able to use or even understand. The complexities of the individual models preclude the thorough investigation of all possible questions. Hence, there are anomolies in the model results which the working group did not pursue. The focus of the EMF study resolved quickly to the measurement and evaluation of the implicit elasticity of substitution embedded in the models, and most of the effort is devoted to the consistent presentation of this somewhat artificial parameter. The remaining data and model comparisons are included for completeness without any warranty as to their potential use.

The graphs are coded to facilitate the comparison across models. All points are plotted by a numeral to identify the corresponding model. The numerals are assigned as follows:

1. PILOT Model
2. Kennedy-Niemeyer Model
3. Wharton Model
4. Hudson-Jorgenson Model
5. Hnyilicza Model
6. DRI-Brookhaven Model
9. History

GROSS NATIONAL PRODUCT

Values are reported in billions of constant 1972 dollars. All of the models treat population growth and technological changes as exogenous parameters. In the presence of constant prices, these assumptions virtually determine the growth rate of the GNP. The similarity of results for the GNP, therefore, is not surprising.

In the High Growth scenario, various mechanisms, such as faster population growth, more rapid technological change, or higher employment levels are used to increase economic activity without large changes in energy prices. This High Growth case is used later in summary statistics to estimate the implied per capita income elasticity of energy demand.

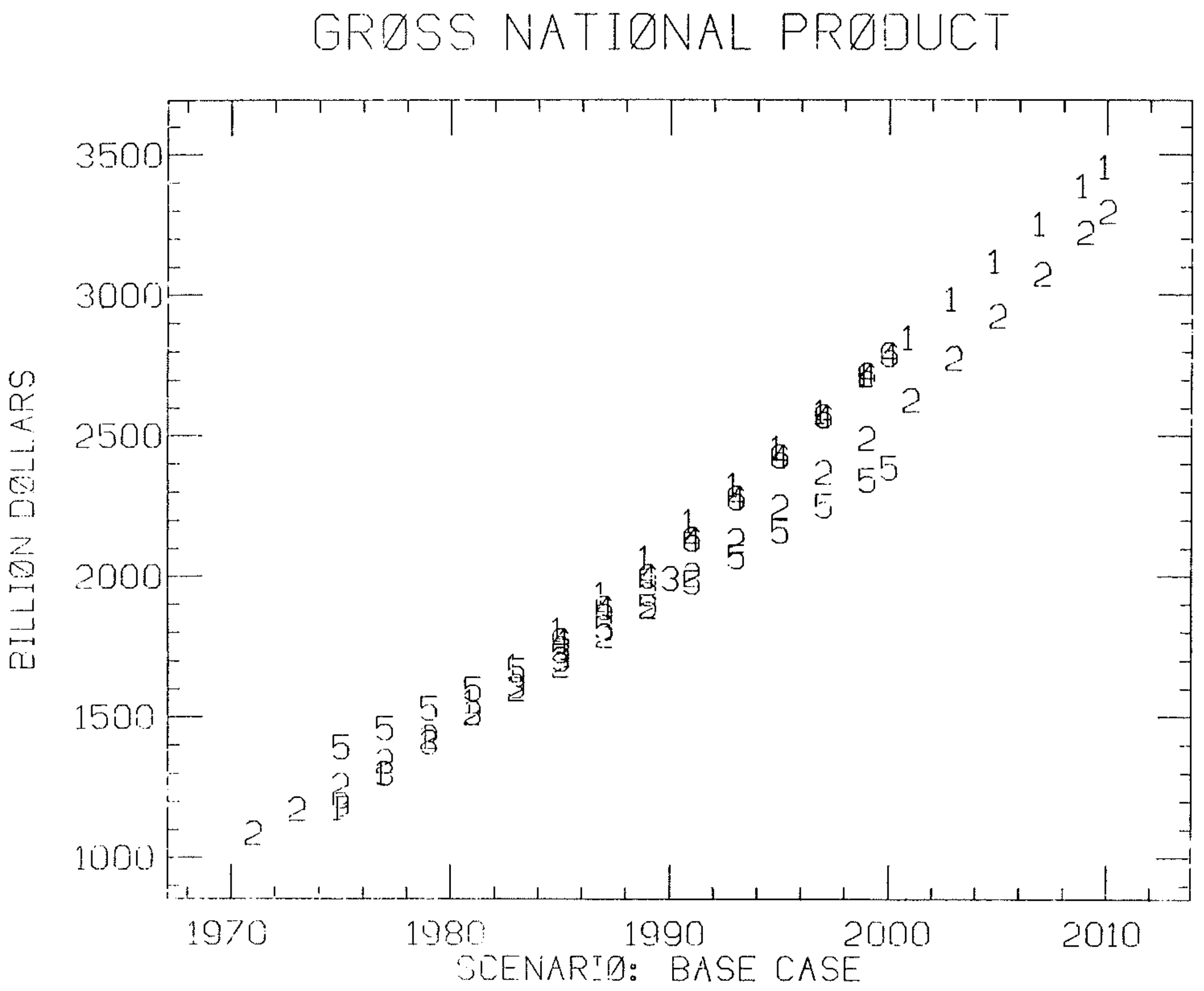

GROSS NATIONAL PRODUCT
BILLION DOLLARS
3500
3000
2500
2000
1500
1000
1970
1980
1990
2000
2010
SCENARIO: BASE CASE
1
2
5
3

Figure F-1

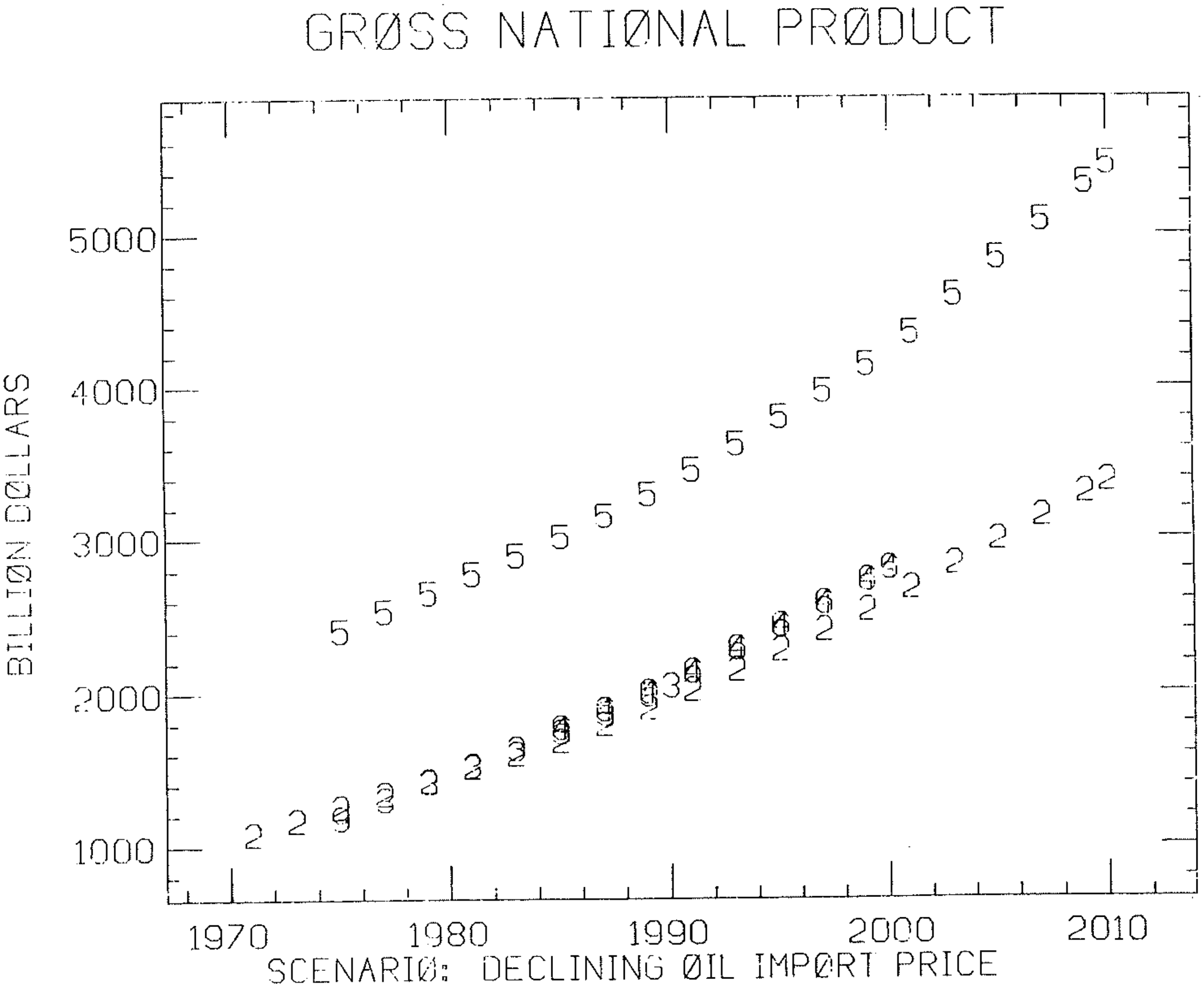

GRØSS NATIØNAL PRØDUCT
BILLIØN DØLLARS
5000
4000
3000
2000
1000
1970
1980
1990
2000
2010
SCENARIØ: DECLINING ØIL IMPØRT PRICE

Figure F-2

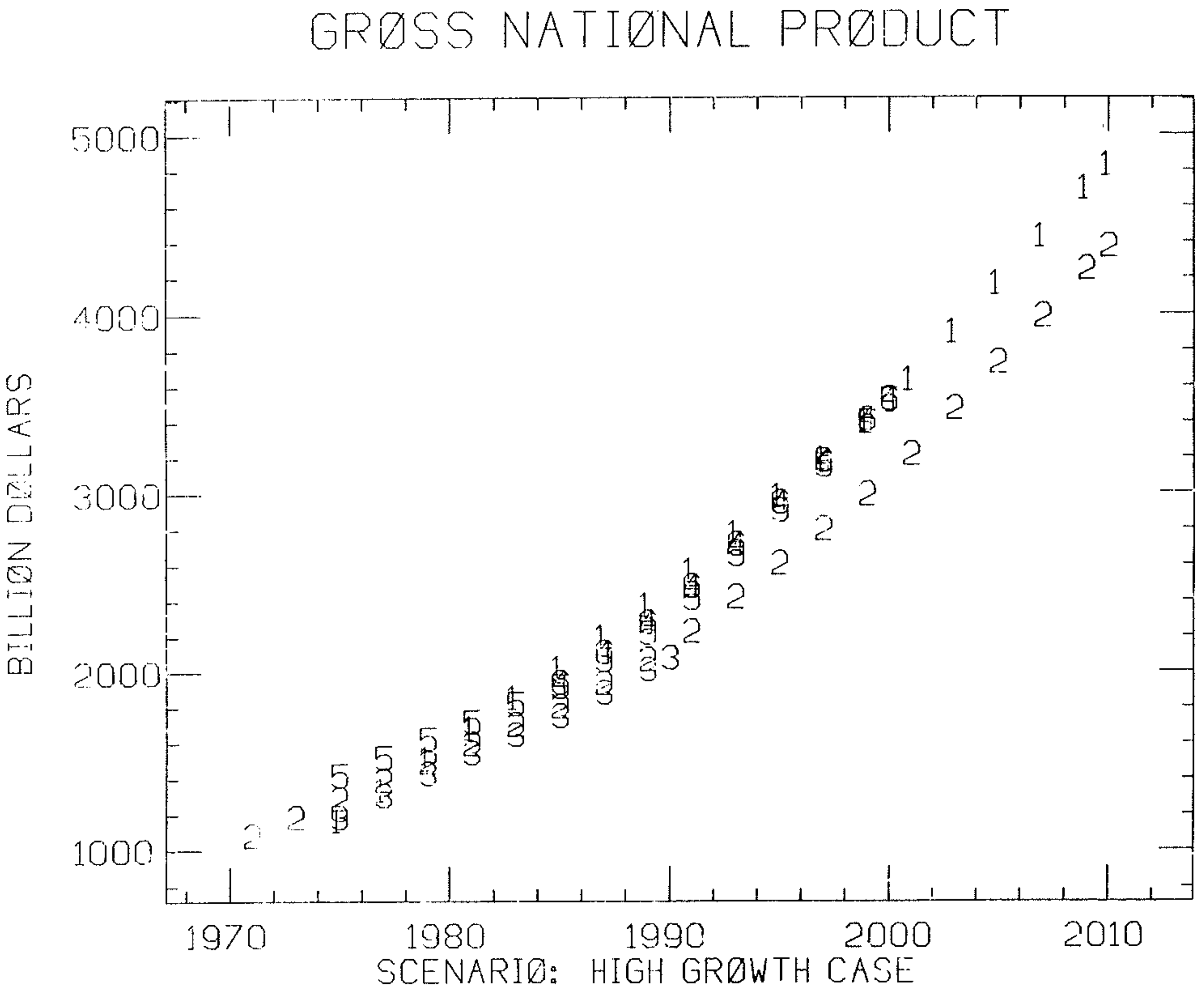

GRØSS NATIØNAL PRØDUCT
BILLIØN DØLLARS
5000
4000
3000
2000
1000
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE

Figure F-3

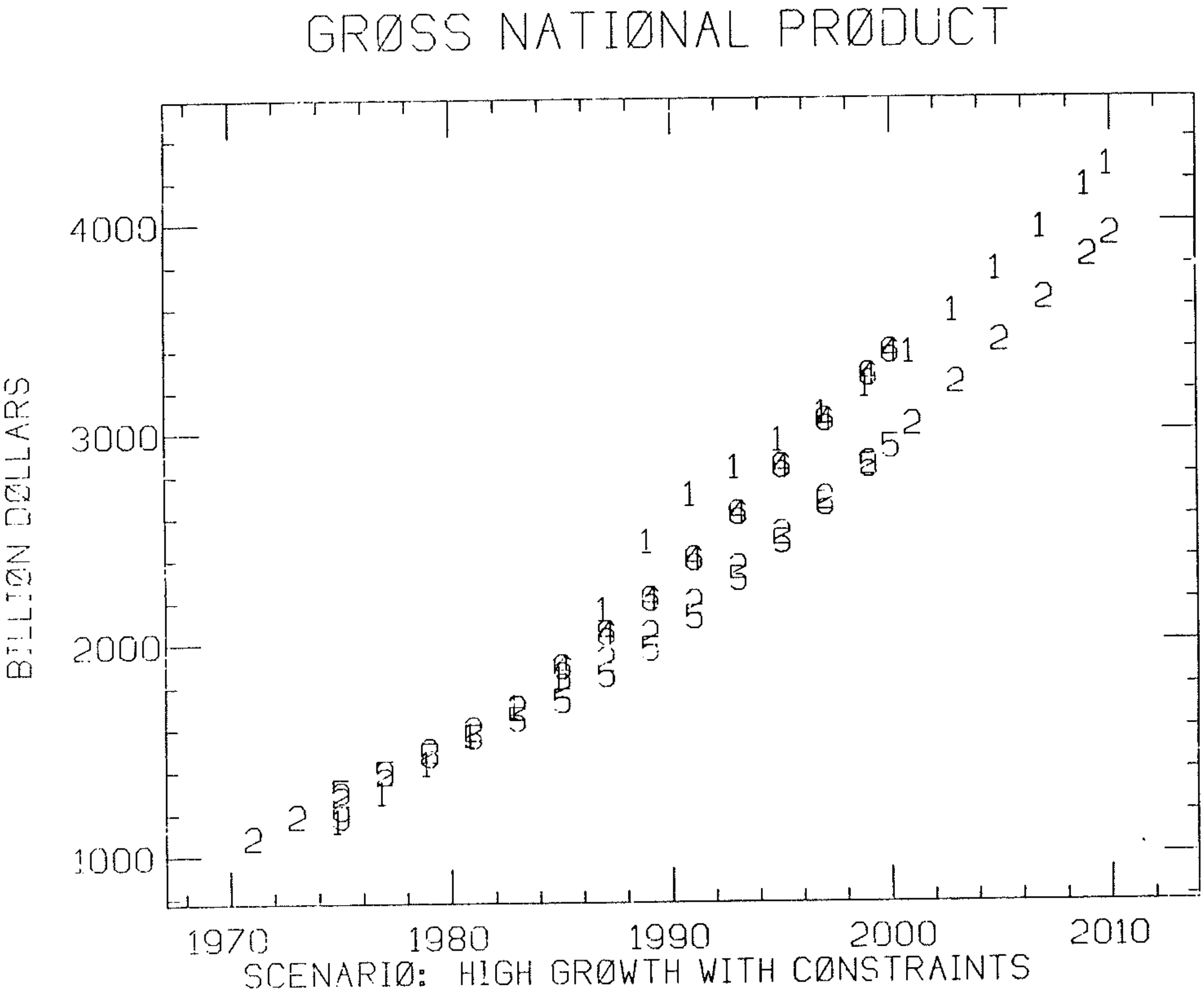

GRØSS NATIØNAL PRØDUCT
BILLIØN DØLLARS
4000
3000
2000
1000
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH WITH CØNSTRAINTS

Figure F-4

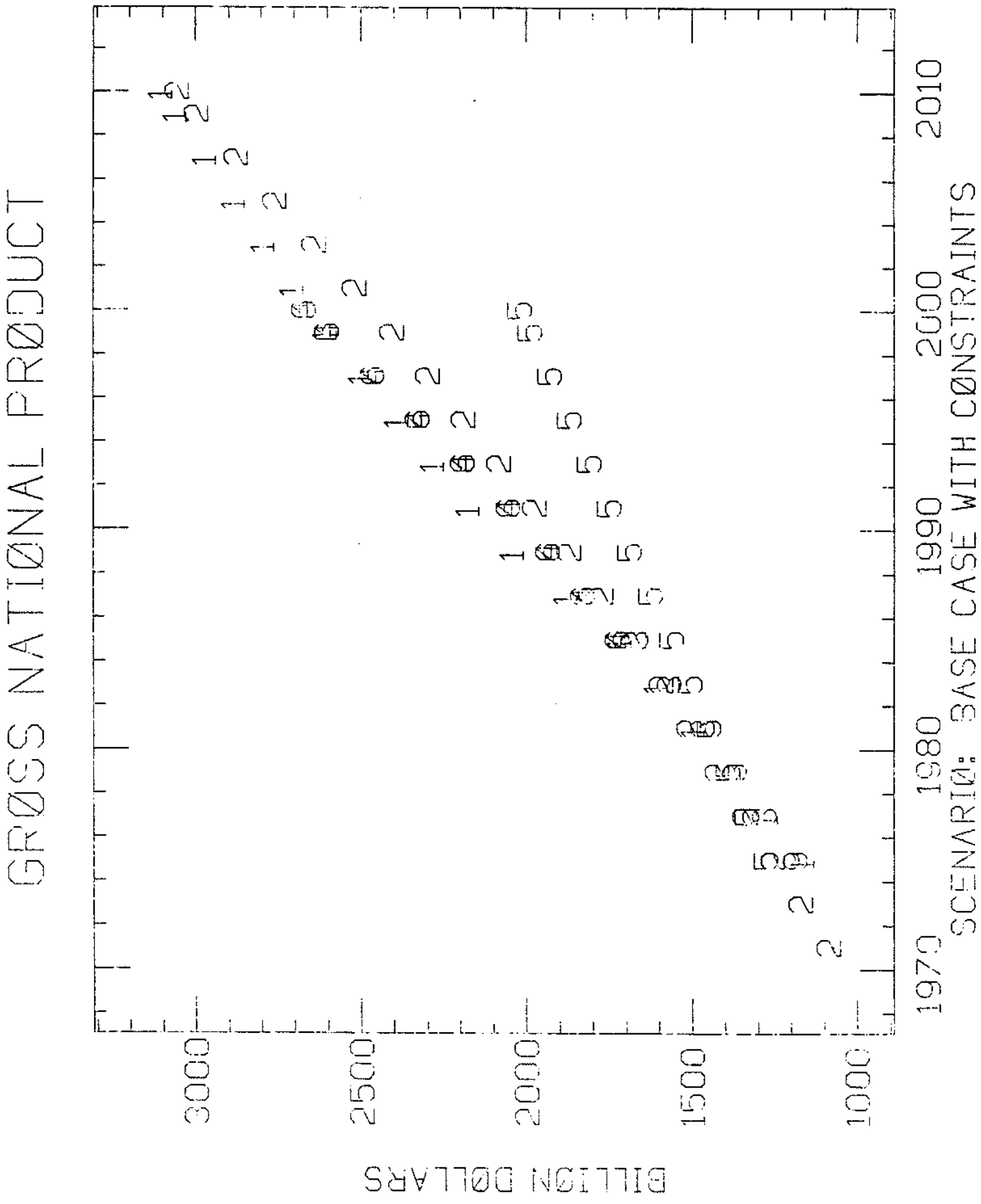

GROSS NATIONAL PRODUCT
SCENARIO: BASE CASE WITH CONSTRAINTS
BILLION DOLLARS
3000
2500
2000
1500
1000
1970
1980
1990
2000
2010
1
2
5
6

Figure F-5

TOTAL QUADS

This is total primary energy input recorded in 10^{15} Btu (quads), following the accounting conventions of the Bureau of Mines. Primary energy input is the most familiar statistic for comparing total energy use, but it has many conceptual deficiencies. For example, the same end use requirements for energy may yield different primary energy inputs, because of different fuel mixes. As a single measure of energy requirements, however, primary energy input is the best available compromise that is widely understood. This measure of energy is used throughout the EMF report and plays a central role in examining the link between energy and the economy.

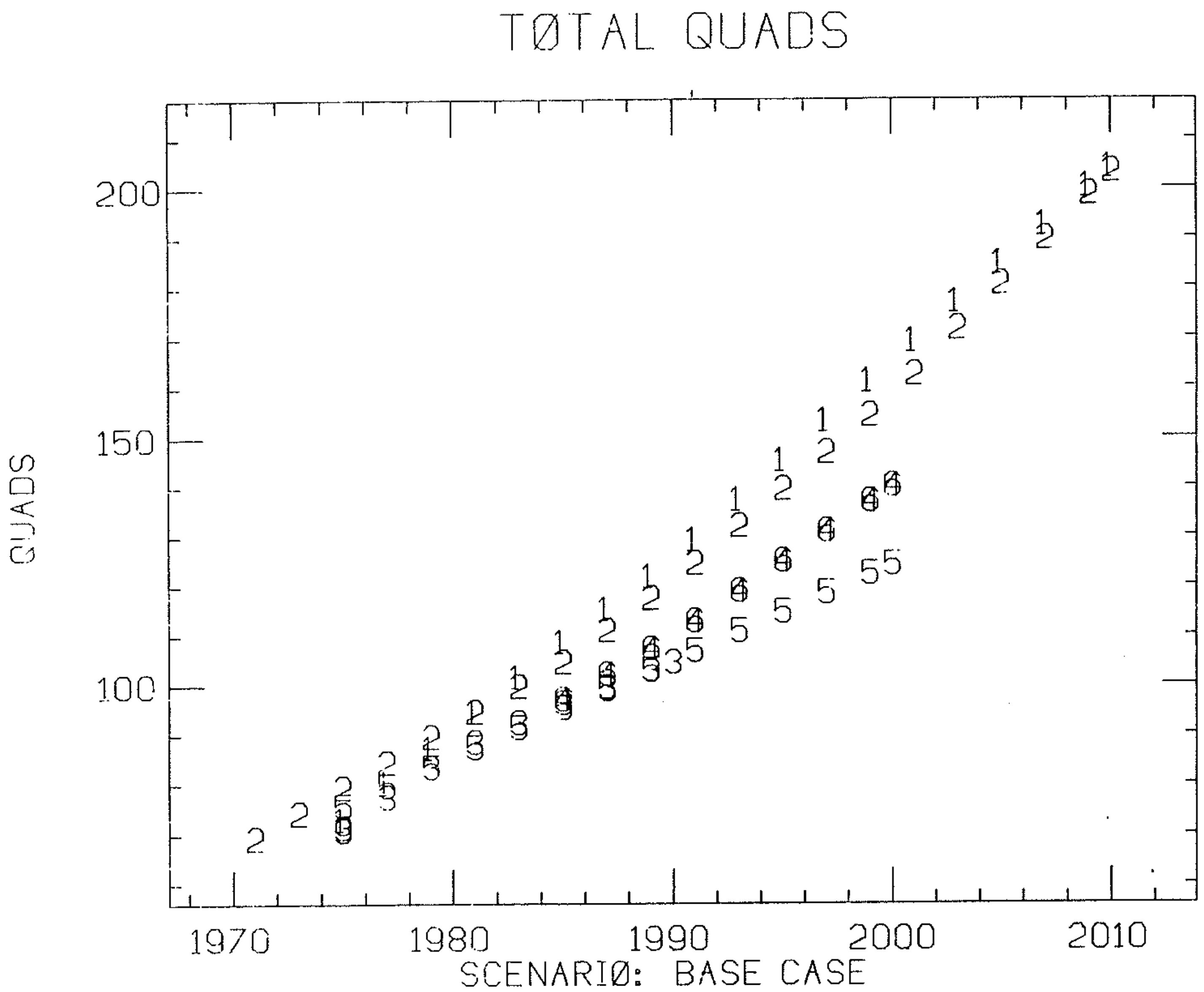

TOTAL QUADS
QUADS
200
150
100
1970
1980
1990
2000
2010
SCENARIO: BASE CASE

Figure F-6

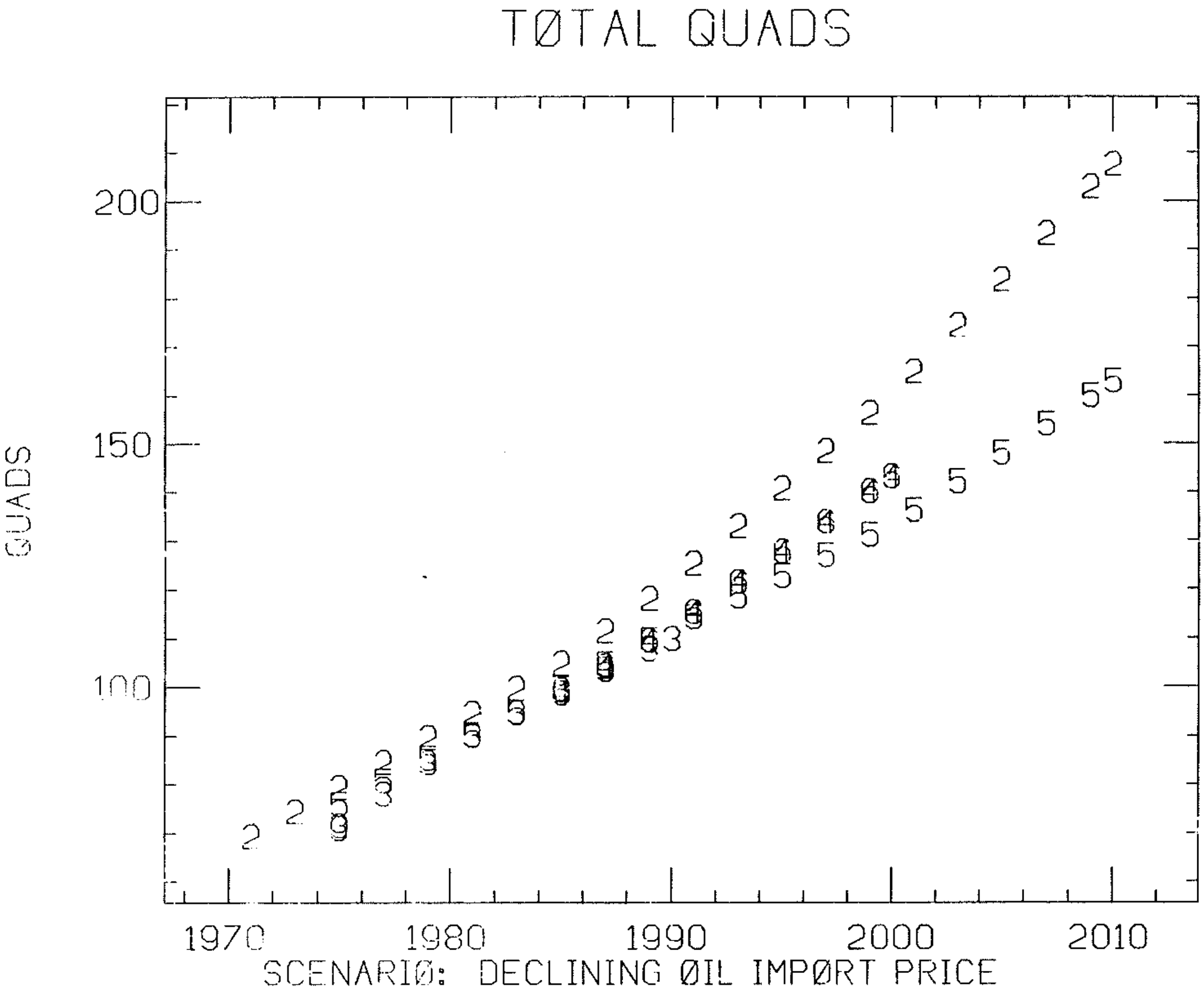
TØTAL QUADS
QUADS
200
150
100
1970
1980
1990
2000
2010
SCENARIØ: DECLINING ØIL IMPØRT PRICE
2
3
4
5
6

Figure F-7

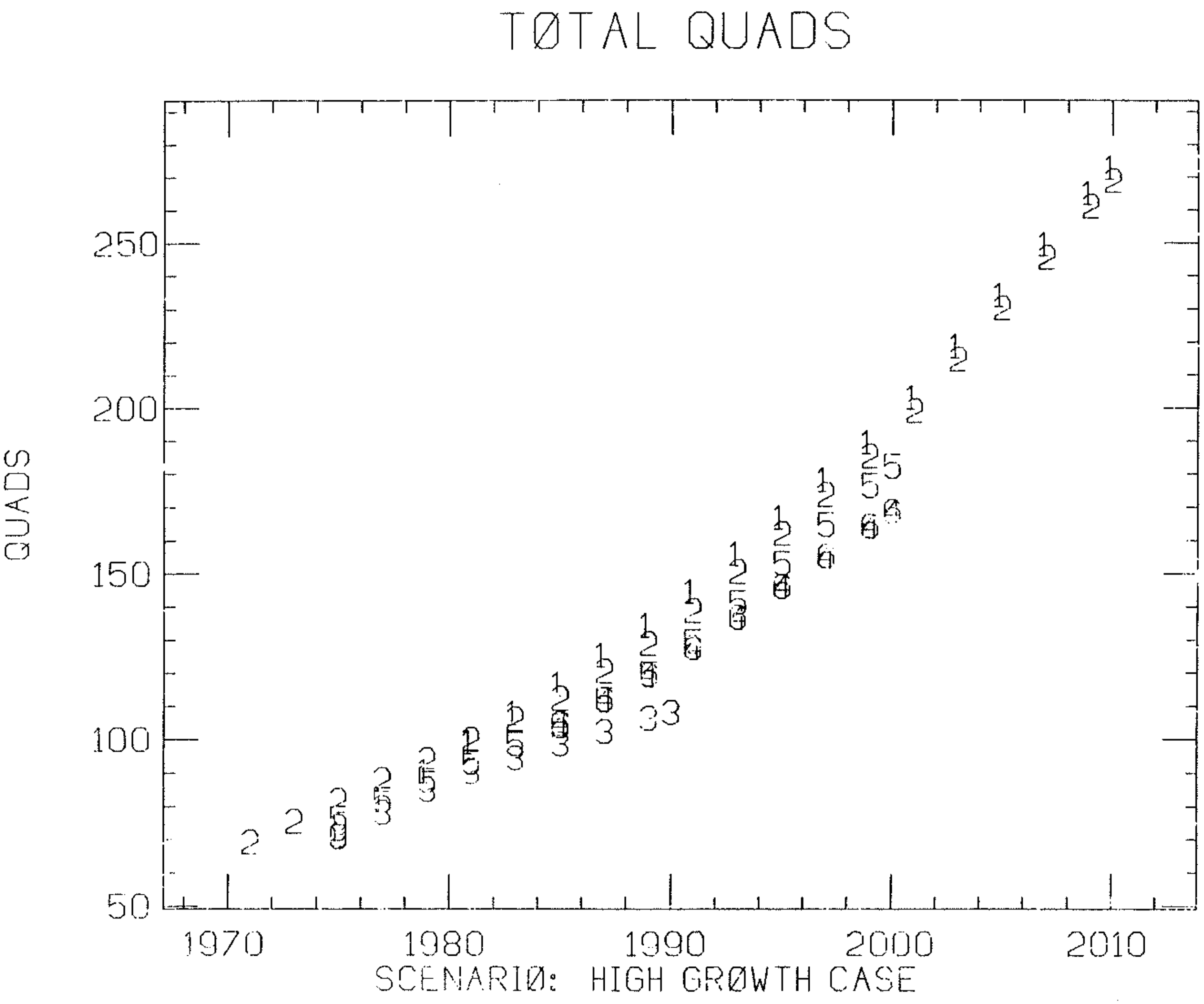

TOTAL QUADS
QUADS
250
200
150
100
50
1970
1980
1990
2000
2010
SCENARIO: HIGH GROWTH CASE

Figure F-8

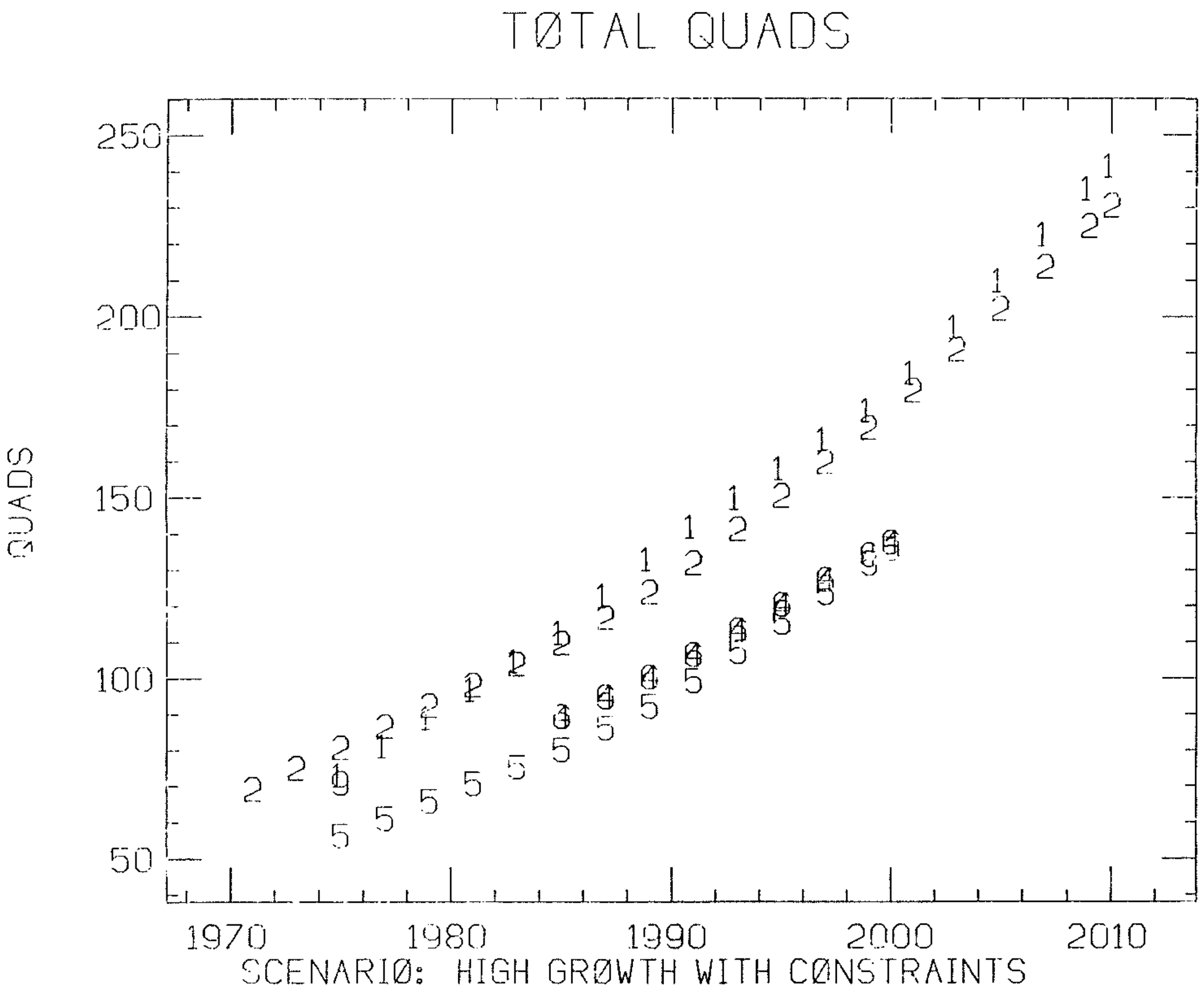

TØTAL QUADS
QUADS
250
200
150
100
50
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH WITH CØNSTRAINTS

Figure F-9

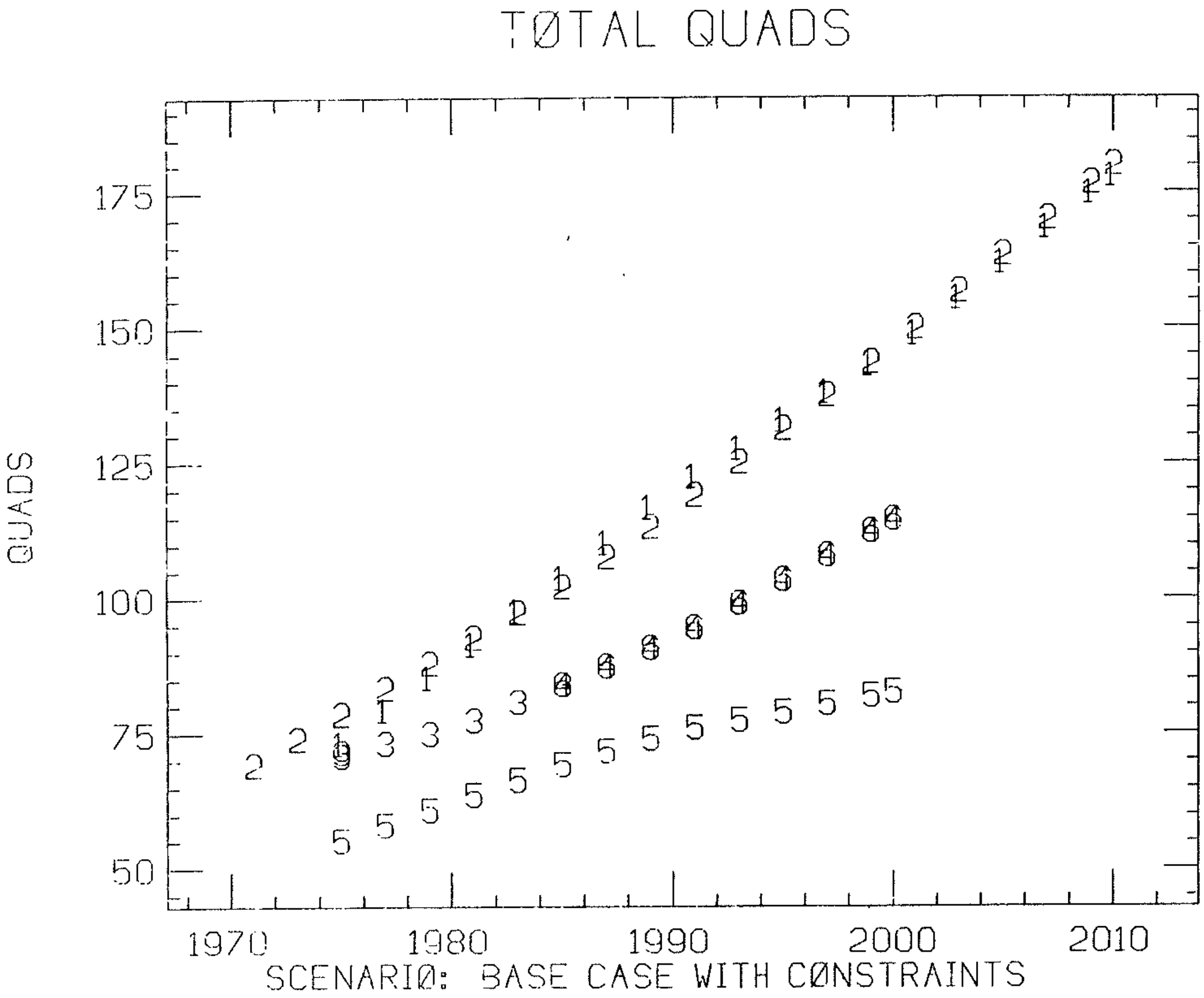

TOTAL QUADS
QUADS
175
150
125
100
75
50
1970
1980
1990
2000
2010
SCENARIO: BASE CASE WITH CONSTRAINTS

Figure F-10

ENERGY-GNP RATIO

This Energy-GNP ratio is defined as:

$$\frac{\text{TOTAL QUADS}}{\text{GROSS NATIONAL PRODUCT}}$$

and is reported in thousand Btu per constant 1972 dollar. It displays one relationship over time between the amount of energy used and the size of the economy, as projected by the various models.

The graph displays the relative difference between the growth rate of the economy and the growth rate of energy. The time path is constant if a one-to-one correspondence is indicated by the models. The time path will decline when the growth rate of energy is less than that of GNP.

The Energy-GNP ratio is indicative of the efficiency of energy use but it is far from the perfect measure. Some limitations of this concept and detailed empirical comparisons of international data are developed in the paper by J. Darmstadter, J. Dunkerley, and J. Alterman, "How Industrial Societies Use Energy: A Comparative Analysis", Resources for the Future Report, Washington, D.C., 1977 [1].

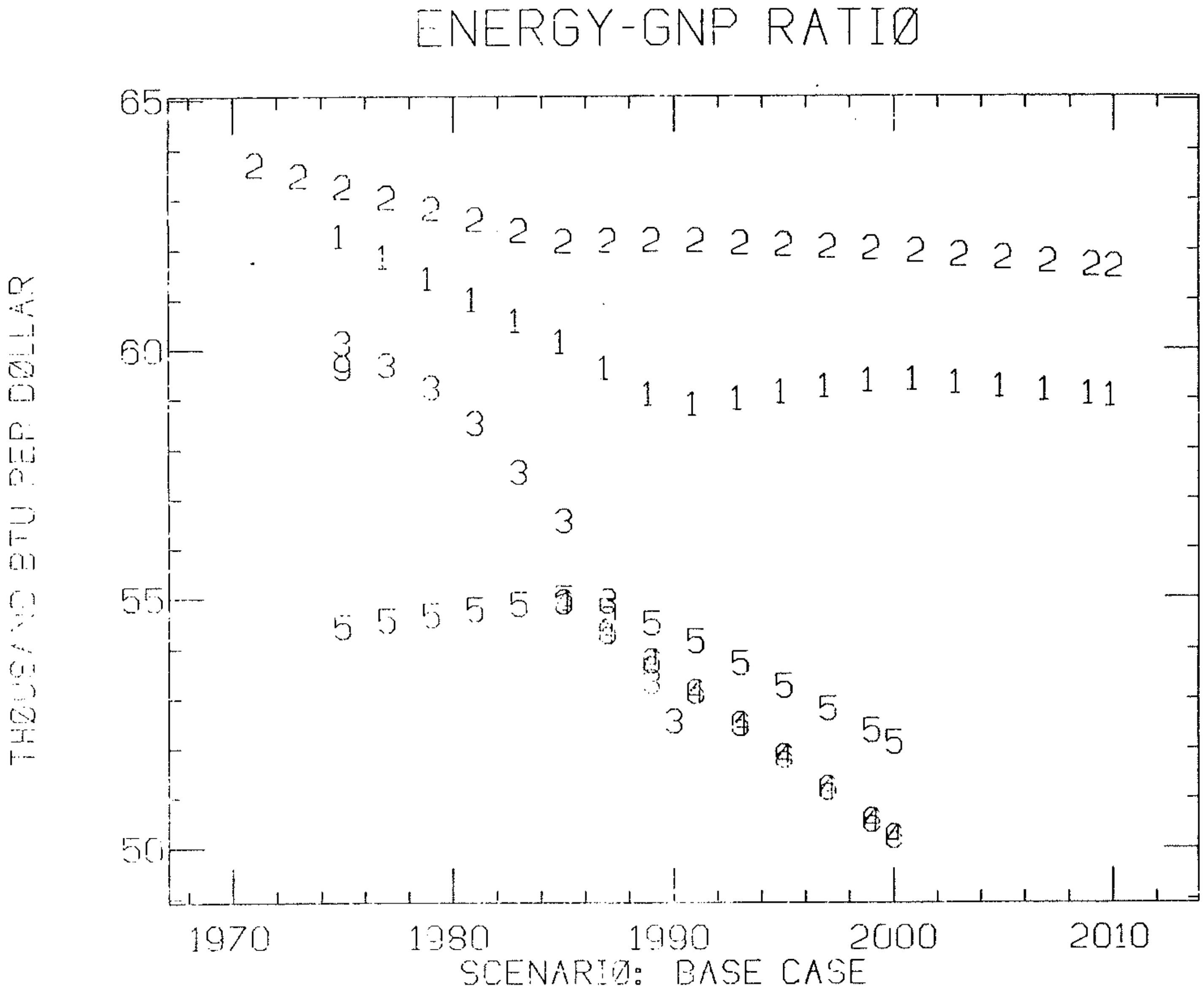

ENERGY-GNP RATIØ
THØUSAND BTU PER DØLLAR
65
60
55
50
1970
1980
1990
2000
2010
SCENARIØ: BASE CASE

Figure F-11

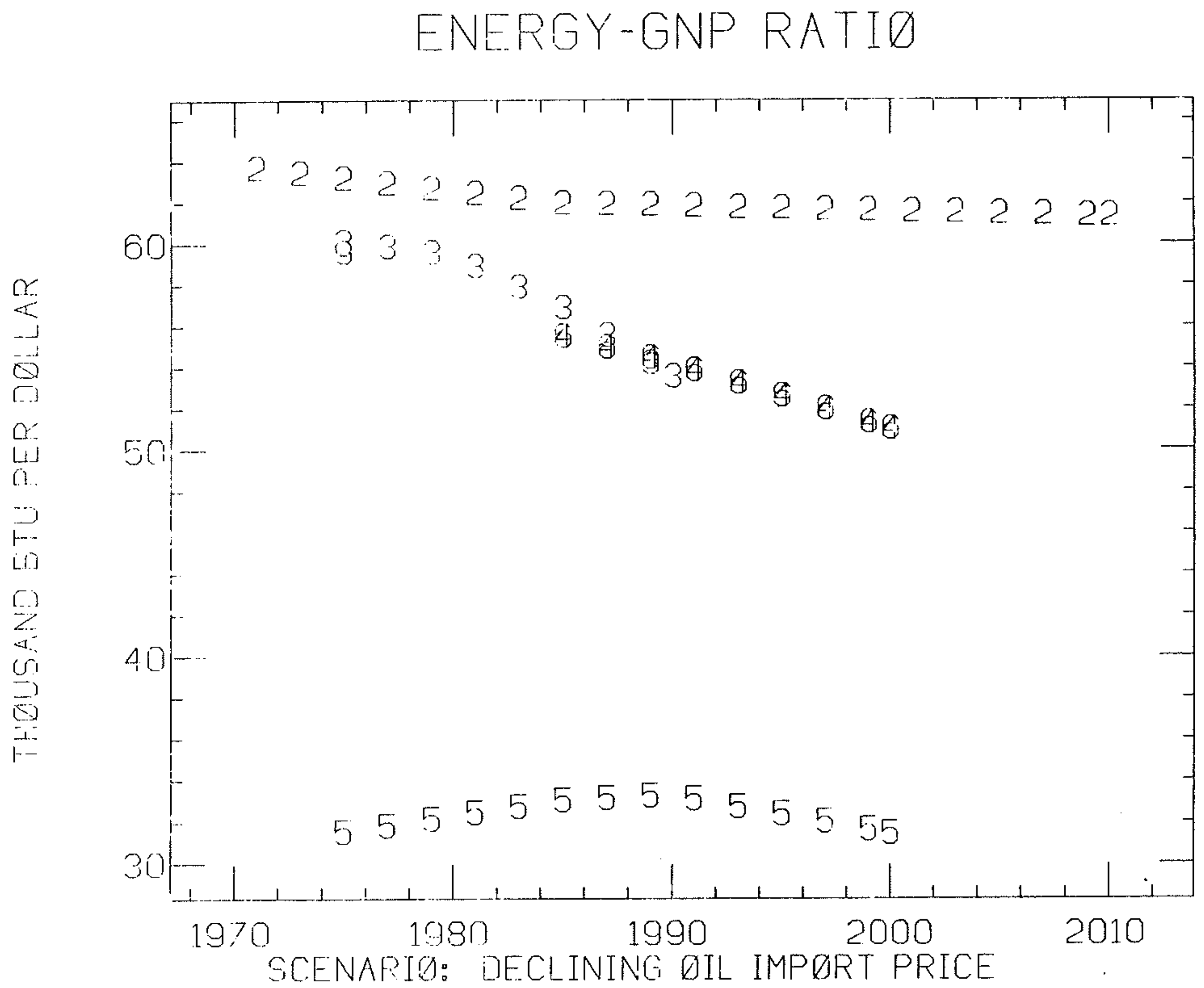

ENERGY-GNP RATIØ
THØUSAND BTU PER DØLLAR
60
50
40
30
1970
1980
1990
2000
2010
SCENARIØ: DECLINING ØIL IMPØRT PRICE
2
3
4
5
6

Figure F-12

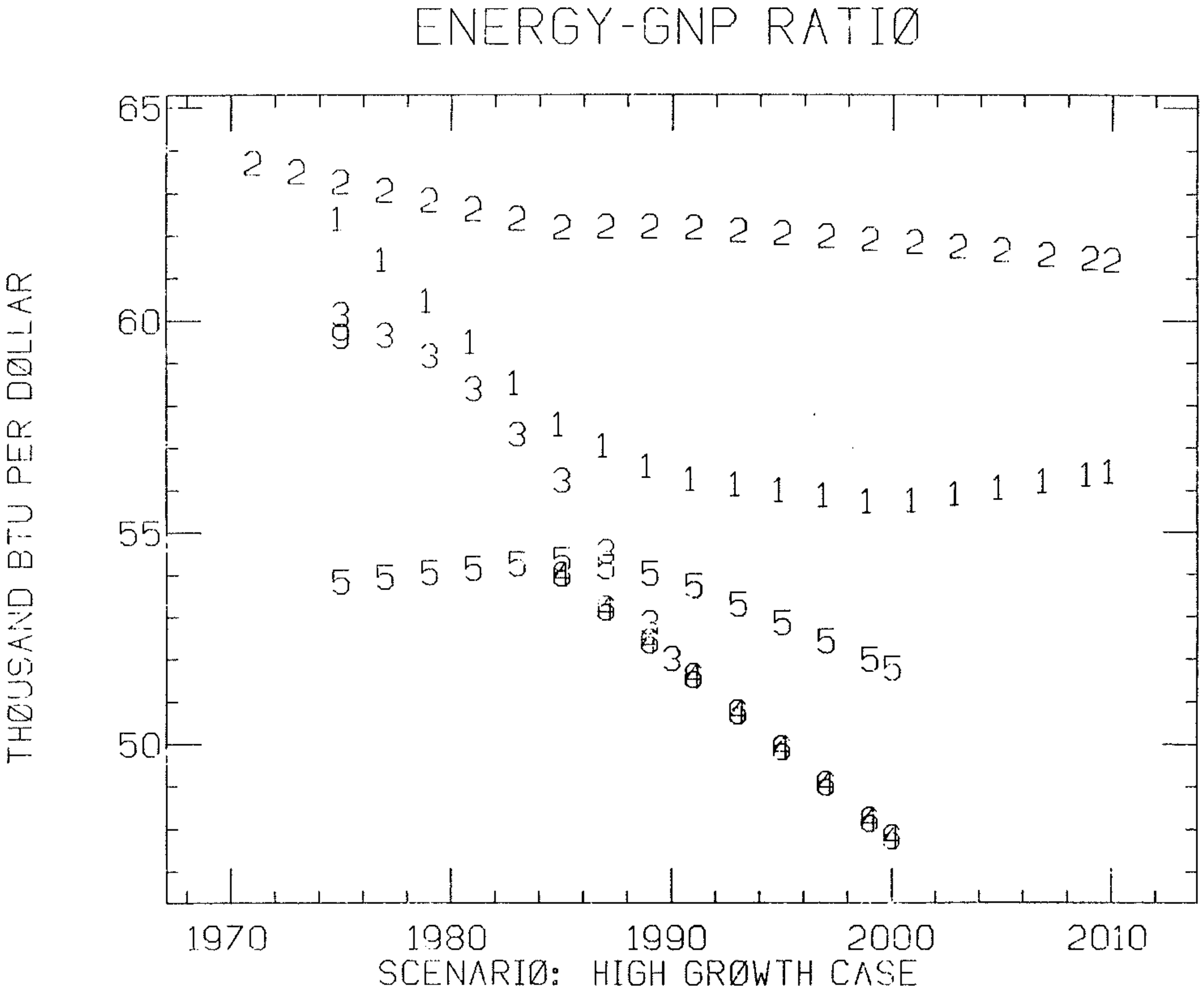

ENERGY-GNP RATIØ
THØUSAND BTU PER DØLLAR
65
60
55
50
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE
1
2
3
4
5
6

Figure F-13

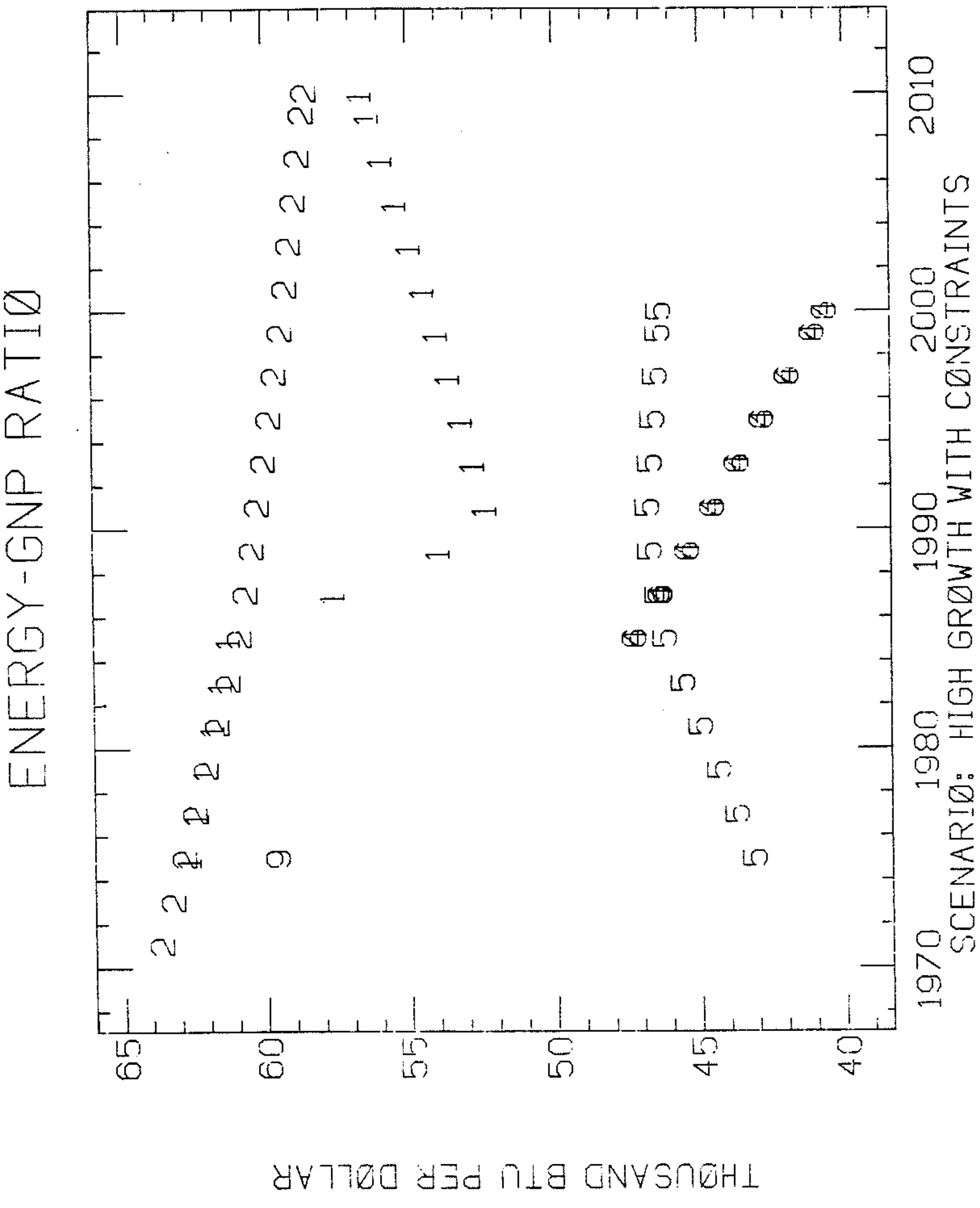

ENERGY-GNP RATIØ
THØUSAND BTU PER DØLLAR
65
60
55
50
45
40
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH WITH CØNSTRAINTS

Figure F-14

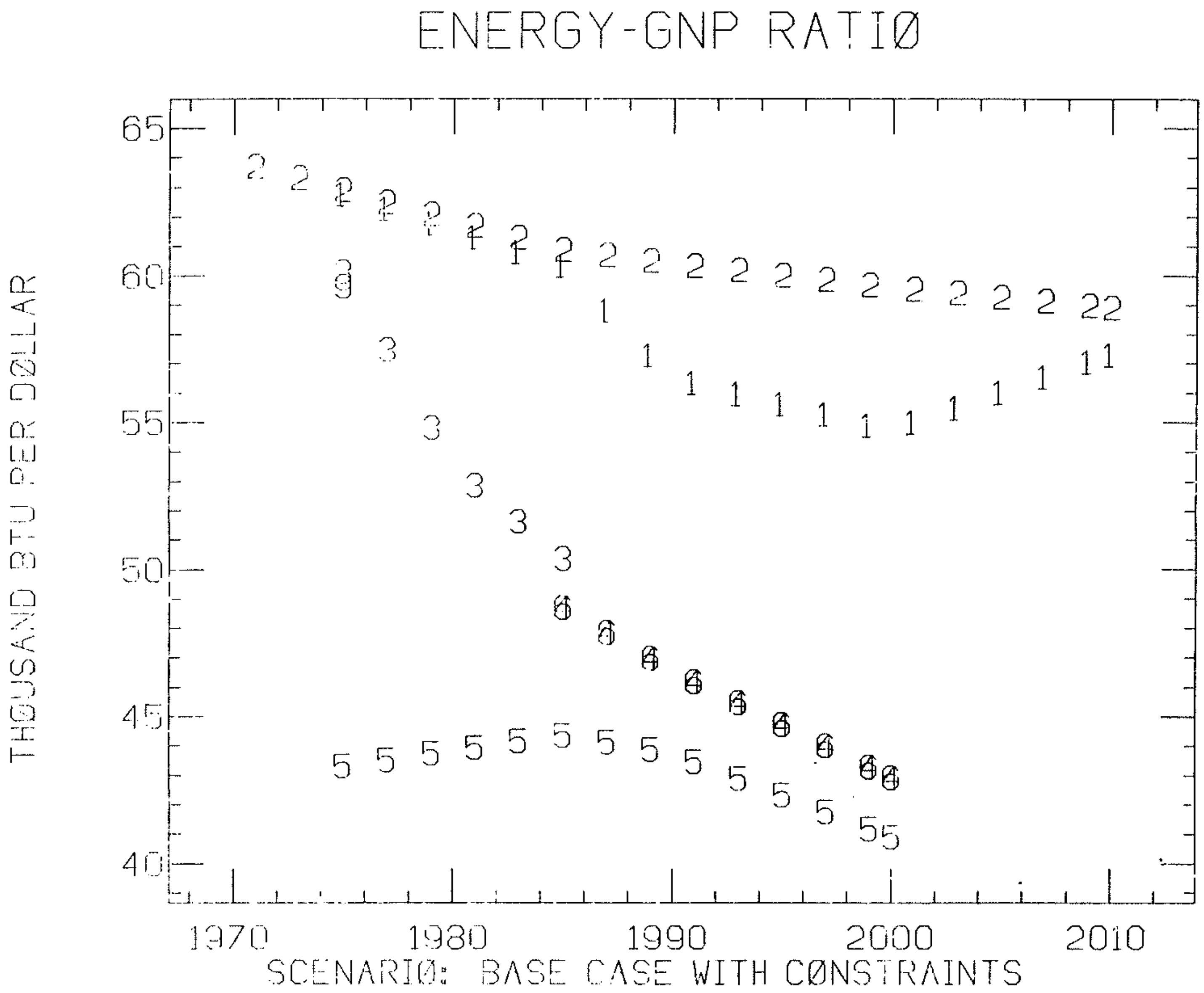

ENERGY-GNP RATIØ
THØUSAND BTU PER DØLLAR
65
60
55
50
45
40
1970
1980
1990
2000
2010
SCENARIØ: BASE CASE WITH CØNSTRAINTS
1
2
3
4
5
6

Figure F-15

NORMALIZED ENERGY-GNP RATIO

This normalized Energy-GNP ratio is defined as:

$$\frac{\text{ENERGY-GNP RATIO}}{\text{BASE CASE ENERGY-GNP RATIO}}$$

This comparative statistic simplified the evaluation of the changes in the Energy-GNP ratio across scenarios when compared to the Base Case. It demonstrates one measure of the flexibility of the energy-economy feedback relations indicated by the various models in comparisons across scenarios. Constant values near 1.0 indicate a strong tie between changes in the energy sector and changes in the economy. A wider dispersion away from 1.0 indicates a flexible energy-economic relationship.

The results for Hnyilicza's model for the Declining Oil Import Price Case are a sharp deviation from those reported for other models and scenarios. This anomoly has not been explained.

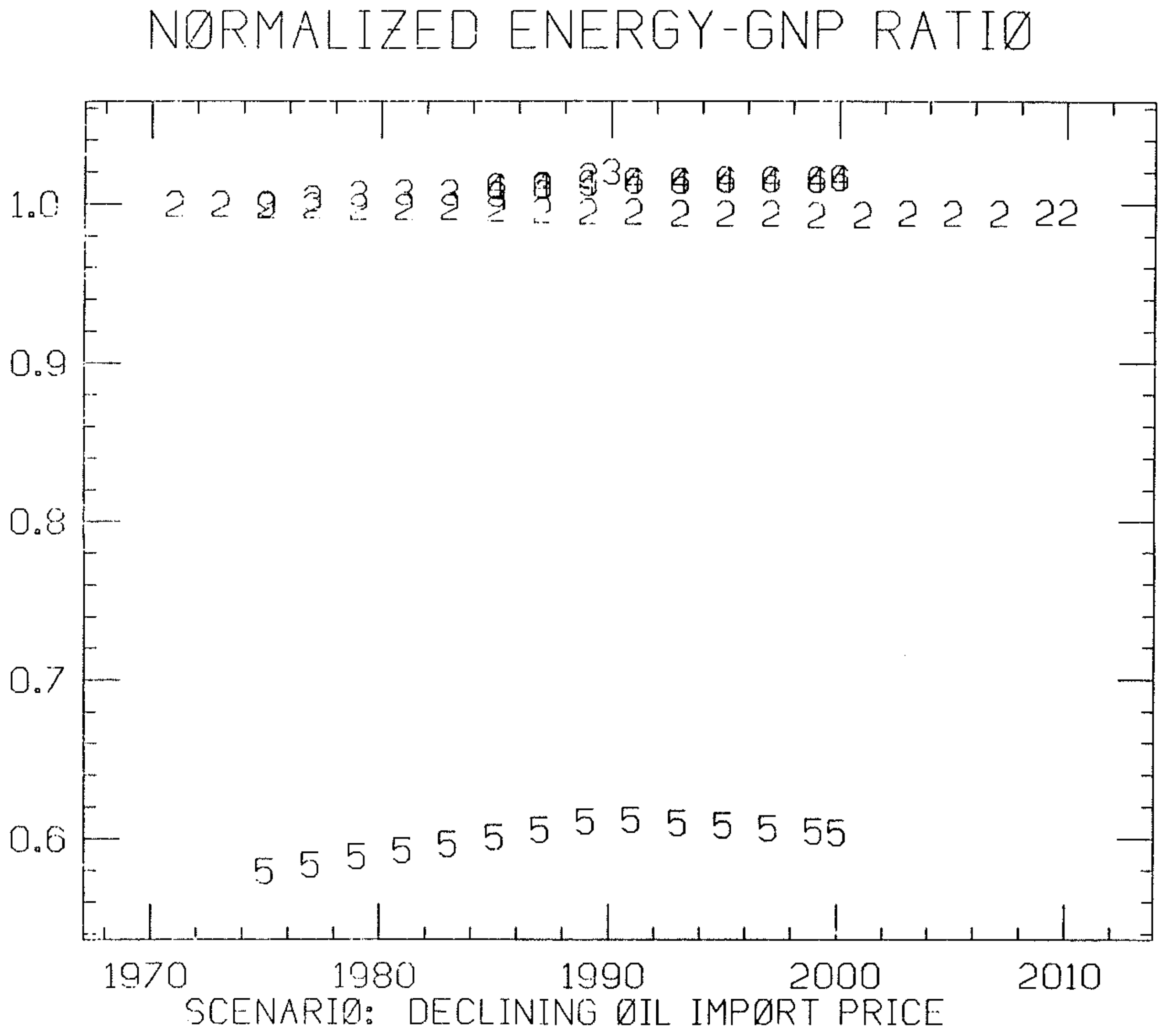

NORMALIZED ENERGY-GNP RATIO
1.0
0.9
0.8
0.7
0.6
1970
1980
1990
2000
2010
SCENARIO: DECLINING OIL IMPORT PRICE

Figure F-16

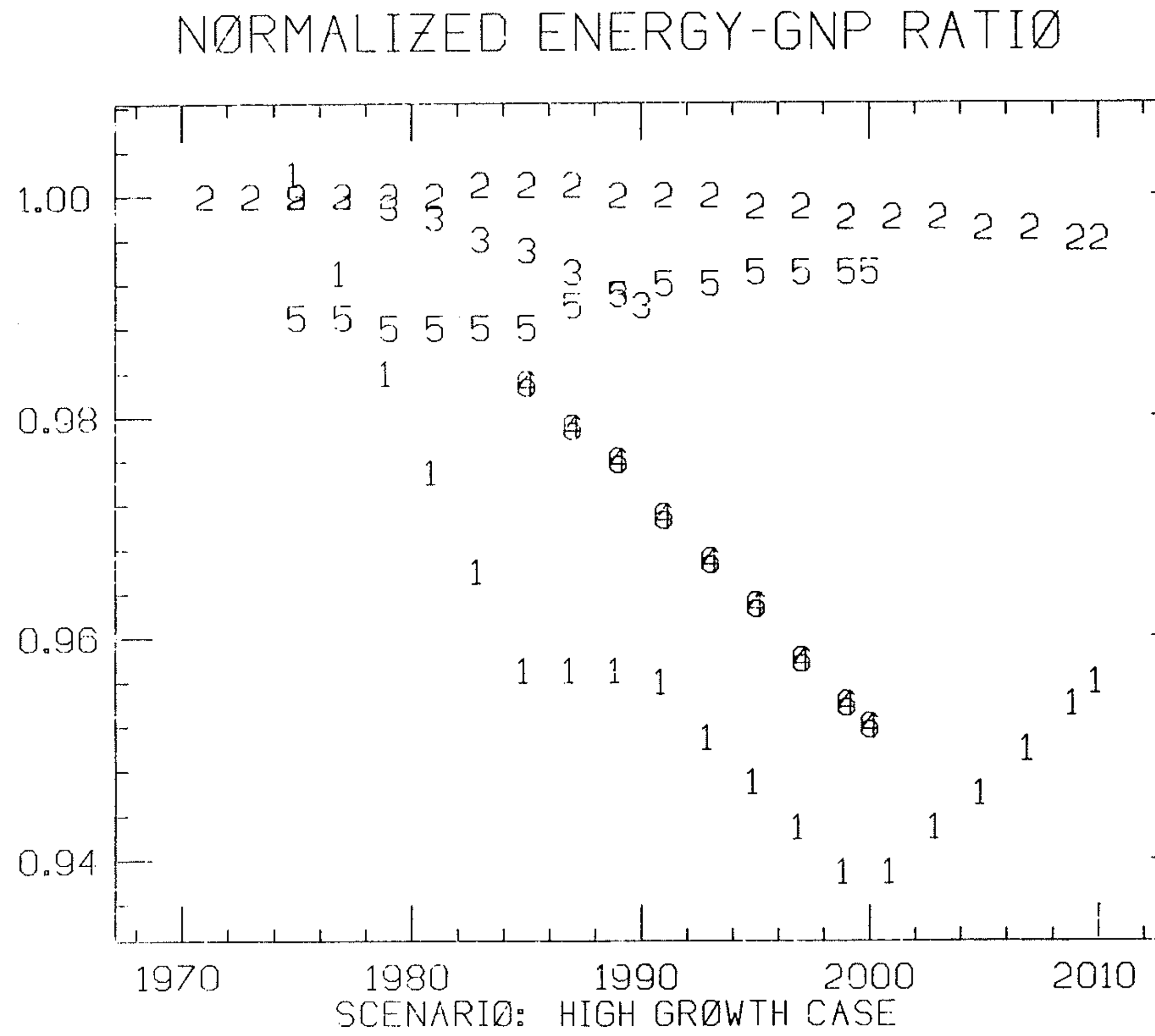

NØRMALIZED ENERGY-GNP RATIØ
1.00
0.98
0.96
0.94
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE

Figure F-17

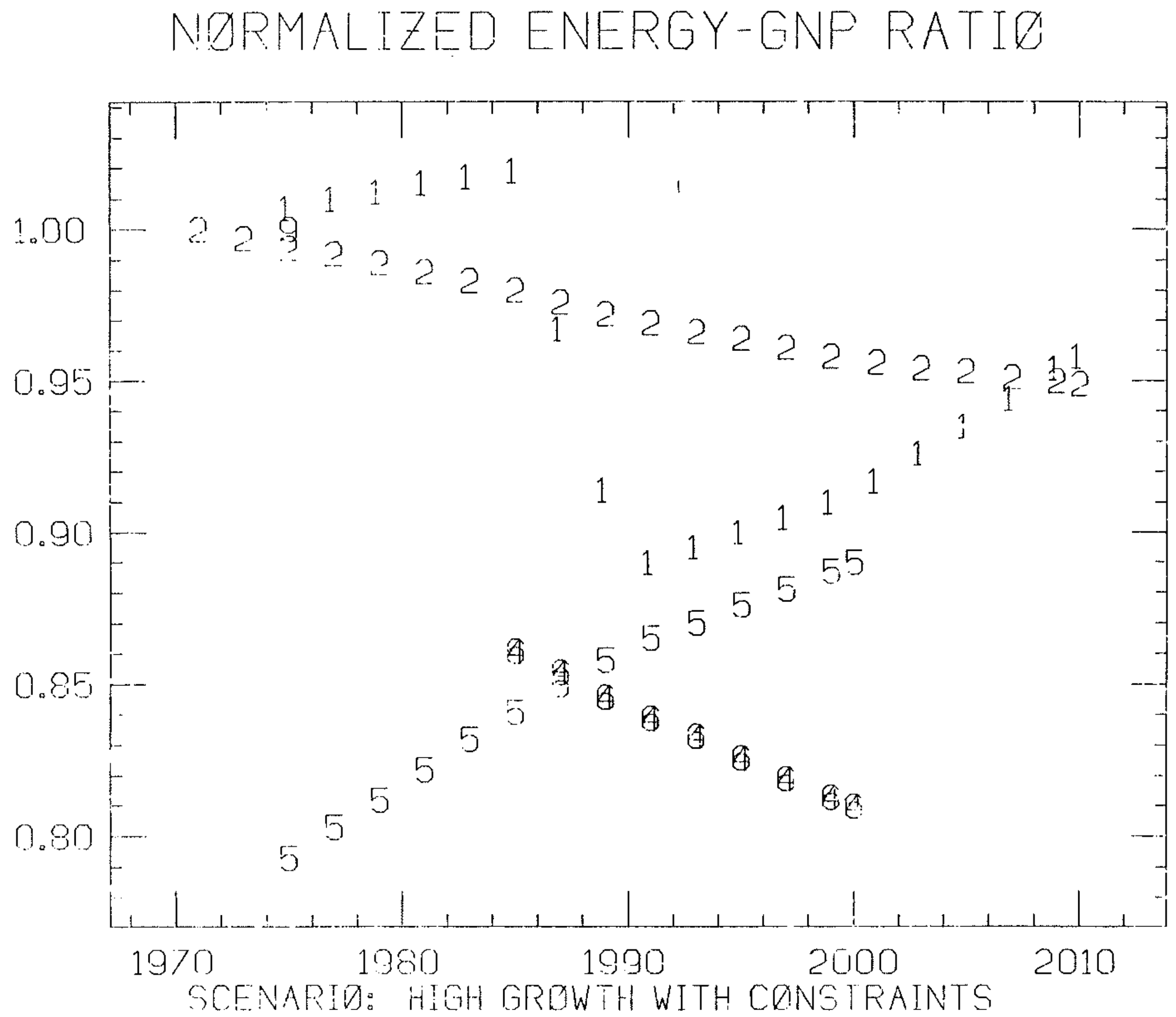

NØRMALIZED ENERGY-GNP RATIØ
1.00
0.95
0.90
0.85
0.80
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH WITH CØNSTRAINTS

Figure F-18

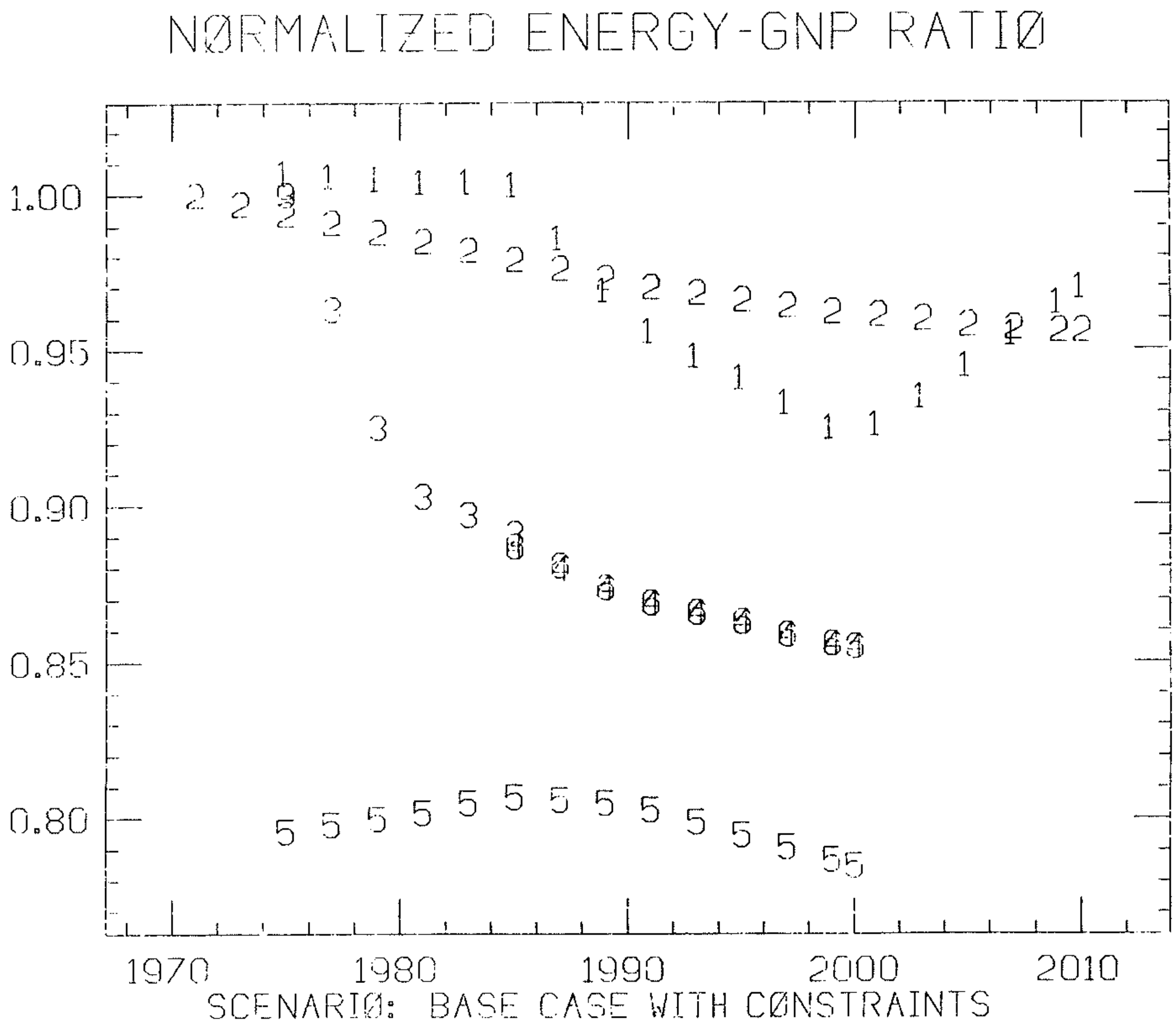

NØRMALIZED ENERGY-GNP RATIØ
1.00
0.95
0.90
0.85
0.80
1970
1980
1990
2000
2010
SCENARIØ: BASE CASE WITH CØNSTRAINTS

Figure F-19

ENERGY IMPORTS

This includes both oil and gas imports and is reported in 10^{15} Btu (quads) per year.

In the Kennedy-Niemeyer model, the value reported for imports includes the amount of AES (alternative energy sources) used. Therefore, the value recorded is higher than the actual imports. As a model without responsiveness to higher prices and a declining domestic production base, the Kennedy-Niemeyer system utilizes a high level of oil and gas imports.

The output from the Wharton model did not include separate reporting of imports.

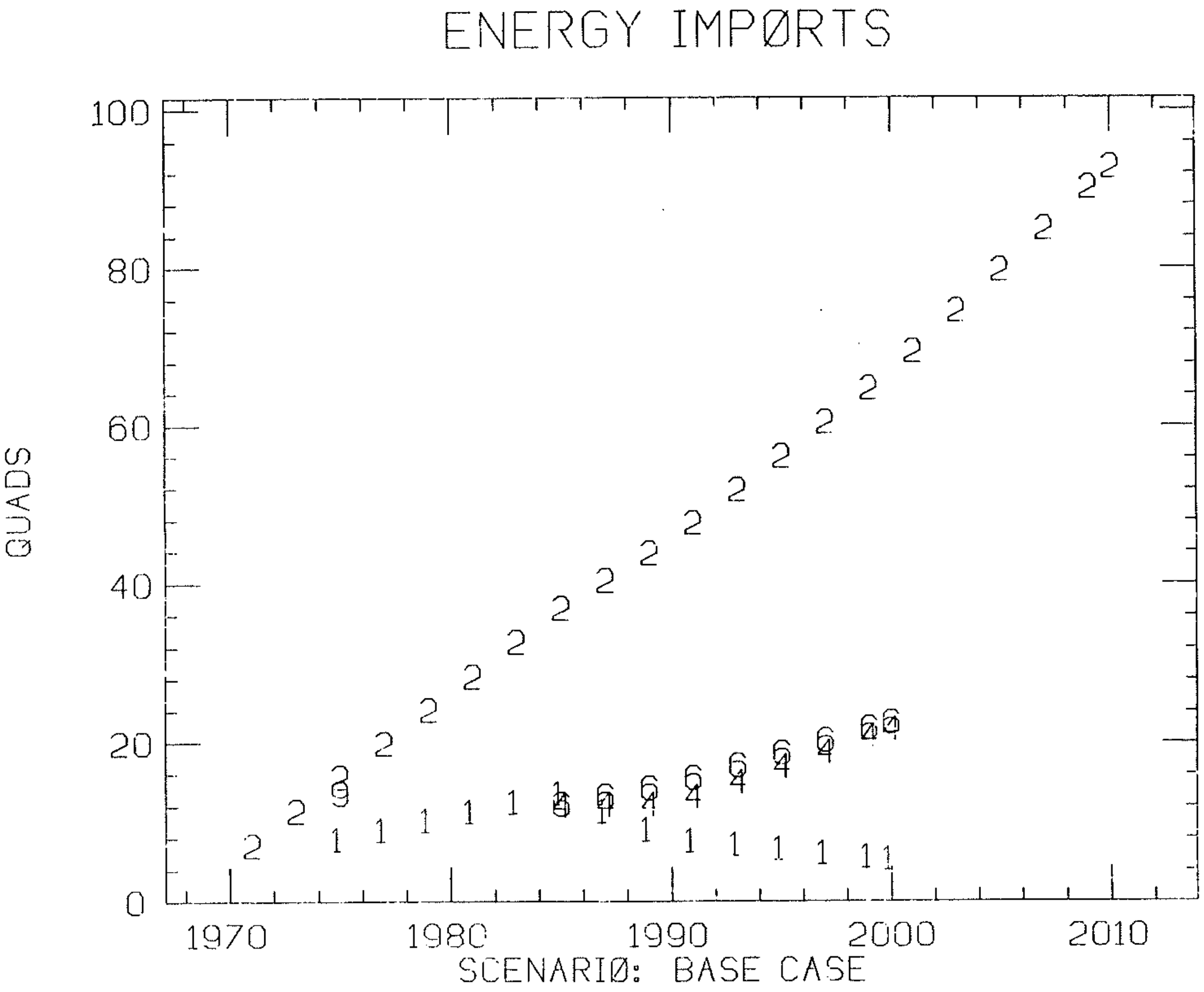

ENERGY IMPORTS
QUADS
100
80
60
40
20
0
1970
1980
1990
2000
2010
SCENARIO: BASE CASE

Figure F-20

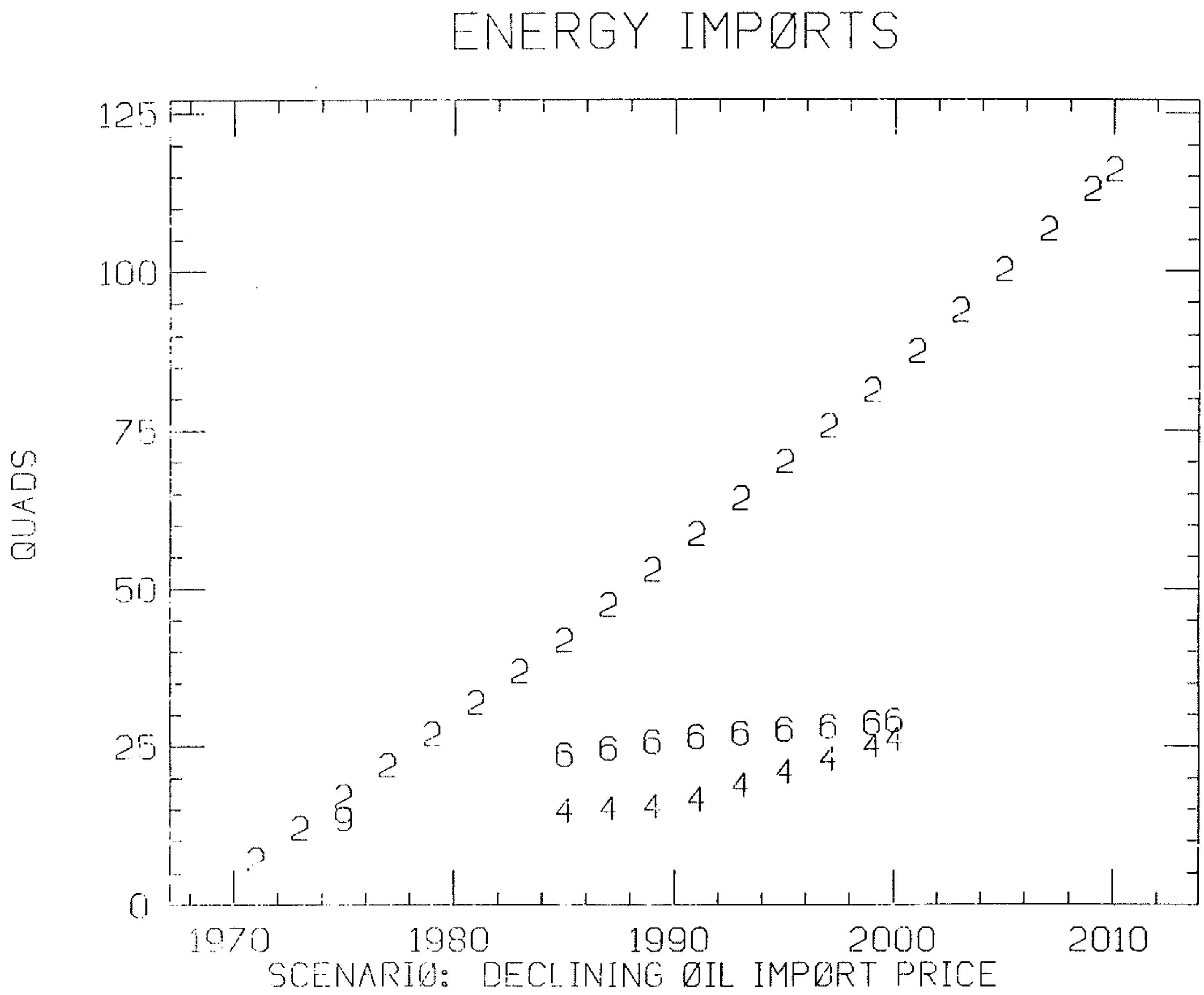

ENERGY IMPØRTS
QUADS
125
100
75
50
25
0
1970
1980
1990
2000
2010
SCENARIØ: DECLINING ØIL IMPØRT PRICE

Figure F-21

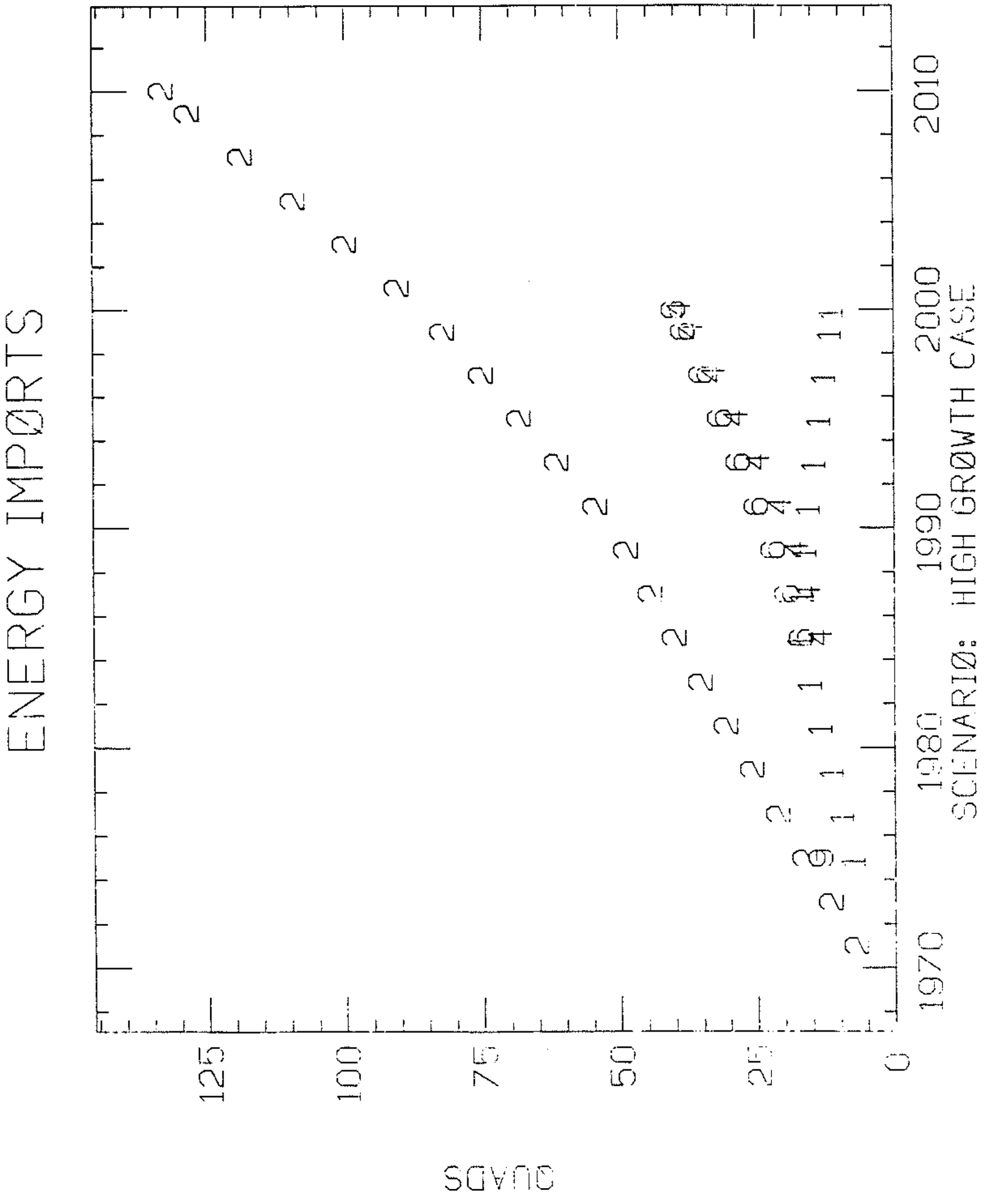

ENERGY IMPØRTS
QUADS
0
25
50
75
100
125
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE

Figure F-22

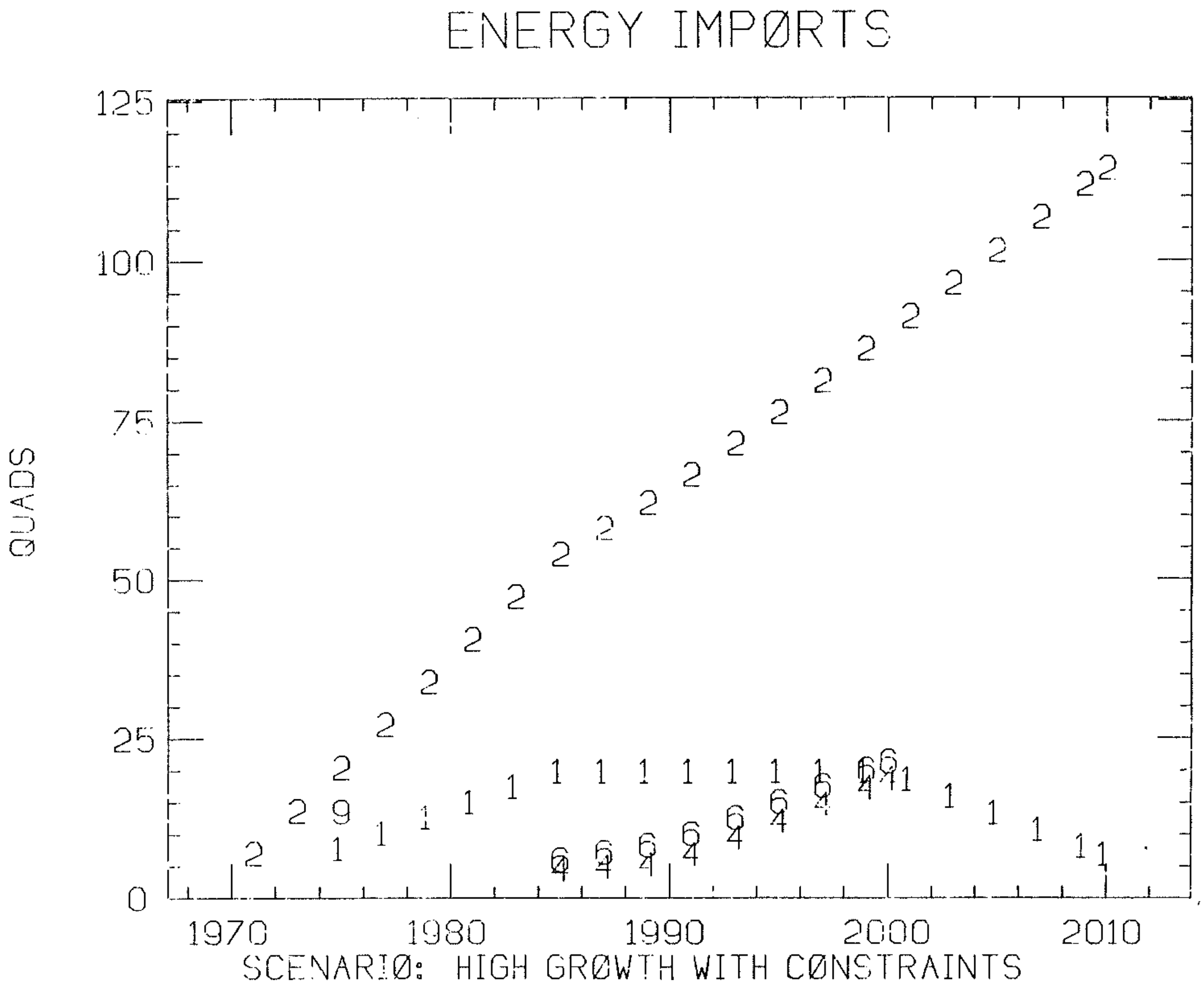

ENERGY IMPØRTS
QUADS
125
100
75
50
25
0
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH WITH CØNSTRAINTS

Figure F-23

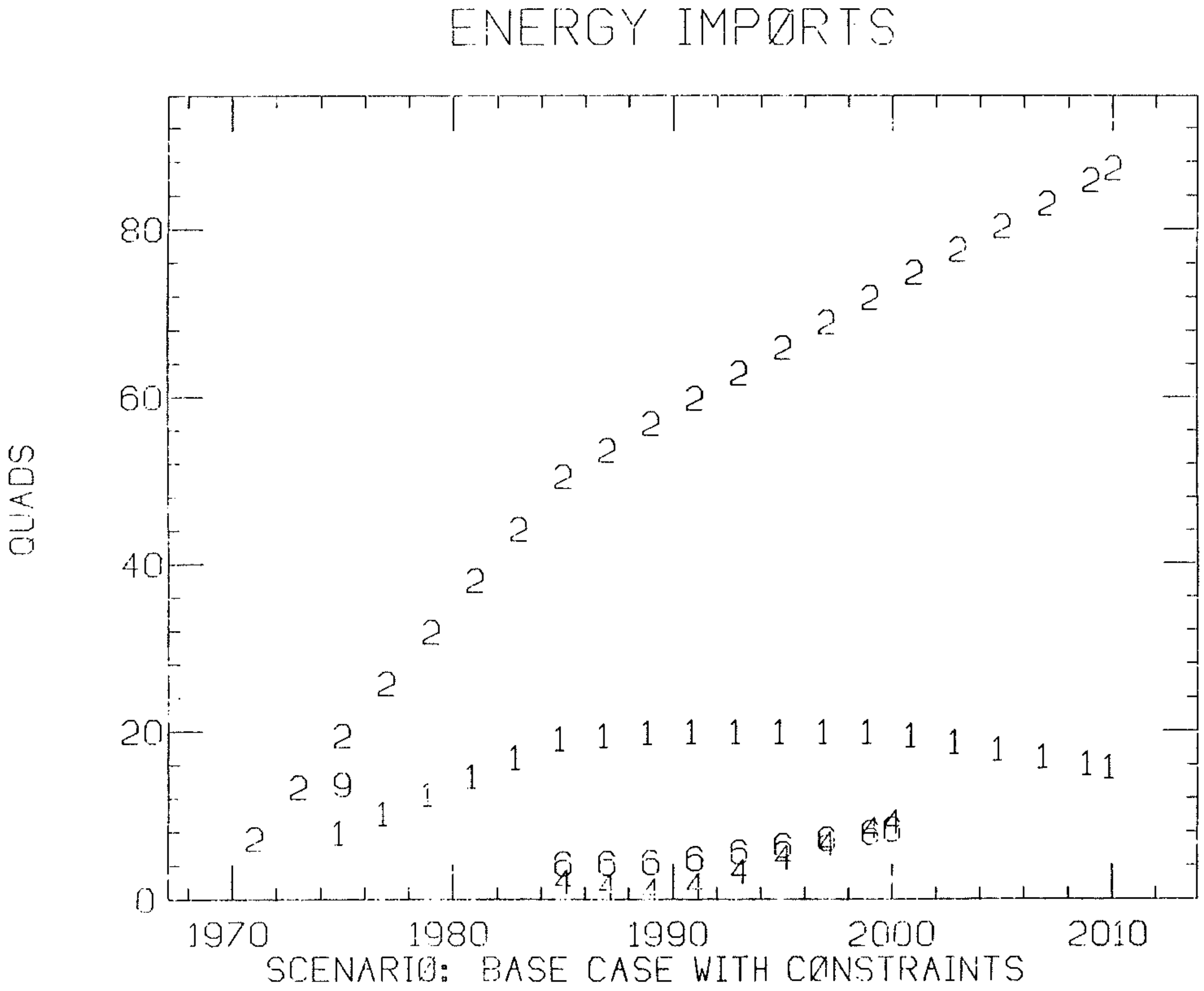

ENERGY IMPORTS
QUADS
0
20
40
60
80
1970
1980
1990
2000
2010
1
2
4
6
9
SCENARIO: BASE CASE WITH CONSTRAINTS

Figure F-24

FOSSIL FUEL PRICE

This is a measure of the cost of primary energy inputs. See the attached Technical Memo EMF-TM-77-1.1 for a definition. The key difficulty here is the use of a homogeneous commodity called "primary energy". This is a fiction of the accounting structure, but it is crucial in the simplied comparison of the models. For the EMF purposes, the proper measure of the price is at the earliest point where the energy enters the system before the costs of fungible capital and labor needed to transform that energy are included in the price. Here, the wellhead or mine mouth prices of the component energy products are used to approximate the primary energy price.

In the case of the Wharton model, no fuel prices are reported, but an aggregate energy price index is supplied. The fossil fuel price for this model is based on this index, where the index 1.00 indicates 22¢/million Btu in 1972 dollars.

For the case of the Hnyilicza model, no fuel detail is supplied. A special procedure was used to compute the fossil fuel price from the output of this model. The attached Technical Memo EMF-TM-77-1.3 summarizes these calculations.

SUBJECT: FOSSIL FUEL PRICE
AUTHOR: D. R. Fromholzer

EMF TECHNICAL MEMO-77-1.1
DATE: 5/6/77

FOSSIL FUEL PRICE

The fossil fuel price is a rough measure of the average price of primary energy inputs. It is based on the prices and expenditure shares of the primary fuels--coal, gas, and oil.

Specifically, the fossil fuel price is defined as:

$$\overline{P}_t = k \prod_{i=1}^{3} p_t^{i\,\overline{\omega}_i} ,$$

where $\overline{P}_t$ = fossil fuel price for time period t ,
p_t^i = price of fuel i in period t ,
$\overline{\omega}_i$ = weights based on expenditure shares. (See exact definition below.)

Also, let
$t = o$ denote the first year reported by a model,
$t = \ell$ denote the last year reported by a model.

We define k so that in the first period the fossil fuel price times the quantity of fossil fuels consumed gives the actual expenditure observed. Thus:

$$\overline{P}_o = \frac{\sum_{i=1}^{3} p_o^i q_o^i}{\sum_{i=1}^{3} q_o^i} ,$$

where q_t^i = quantity of fuel i used in period t .

Then k is generated by solving:

$$\log k = \log \overline{P}_o - \sum_{i=1}^{3} \overline{\omega}_i \, p_o^i .$$

Finally, the weights $\overline{\omega}_i$ are set to be the average expenditure share for each fuel between the first and last periods reported,

$$\overline{\omega}_i = \frac{1}{2} \frac{p_o^i q_o^i}{\sum_{i=1}^{3} p_o^i q_o^i} + \frac{1}{2} \frac{p_\ell^i q_\ell^i}{\sum_{i=1}^{3} p_\ell^i q_\ell^i} .$$

SUBJECT: COMPUTING IMPLIED FOSSIL FUEL PRICES FROM HNYILICZA'S MODEL

EMF TECHNICAL MEMO-77-1.3

AUTHOR: William W. Hogan

DATE: 3/18/77

The available data from Hnyilicza's model are price indices for delivered energy in the intermediate and consuming sectors. We wish to compute an implied price of primary fossil fuels.

Let:

P_{Em}^{t} : real price of intermediate energy in '58 dollars from Hnyilicza.

P_{E}^{t} : real price of primary fossil energy in '58 dollars.

δ_t : ratio of delivered energy to primary energy.

EL_t : percent gross energy devoted to production of electricity.

α_t : cost of transporting, converting, and marketing energy.

Then we assume,

$$P_{Em}^{t} = \alpha_t + P_E^{t} / \delta_t$$

where

$$\delta_t = 1/3\ EL_t + (1-EL_t) \quad .$$

Assuming also that there is technological change in the energy sector of 1.2%/year, then

$$\alpha_t = \alpha_{58}\ (1 - .012)^{t-58} \quad .$$

Now, from Hnyilicza's model we have

$$P_{Em}^{58} = 1.32$$

$$P_E^{58} = .39$$

$$\delta_{58} = .883 \qquad (EL_{58} = .176)$$

and, therefore,

$$\alpha_{58} = .878 \quad .$$

For the purposes of the EMF forecasts we assume

$$EL_{2000} = .4$$

then

$$\delta_{2000} = .73$$

and, therefore,

$$P_E^{2000} = \left(P_{Em}^{2000} - \alpha_{2000}\right) \delta_{2000}$$

$$P_E^{2000} = P_{Em}^{2000} (.73) - .53 (.73).$$

This gives the transformation from Hnyilicza's prices to the implied price of primary fossil energy measured in 1958 $

$$P_E^{2000} = .73 P_{Em}^{2000} - .39 .$$

The real price of intermediate energy in any year is determined by the intermediate energy index from Hnyilicza's ($\bar{P}_{Em}^{2000}$), the GNP deflator ($\bar{P}_{GNP}^{2000}$) and the value of P_{Em}^{58} as

$$P_{Em}^{2000} = \bar{P}_{Em}^{t} \cdot P_{Em}^{58} / \bar{P}_{GNP}^{2000} .$$

Finally the link between Hnyilicza's reported index $\bar{P}_{Em}^{t}$ and the real price of primary fossil energy is

$$P_E^{2000} = .96 \bar{P}_{EM}^{2000} / \bar{P}_{GNP}^{2000} - .39.$$

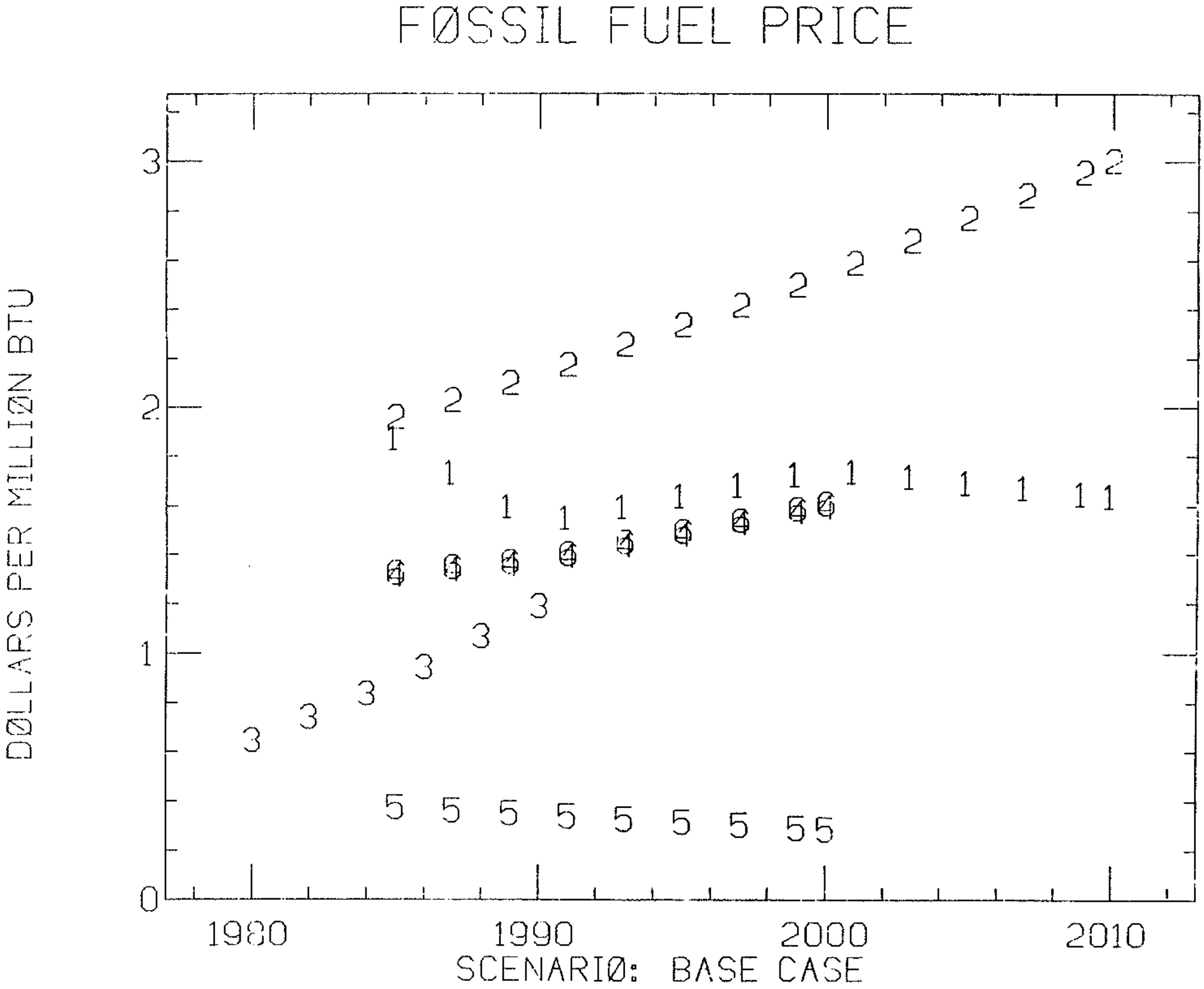

FØSSIL FUEL PRICE
DØLLARS PER MILLIØN BTU
0
1
2
3
1980
1990
2000
2010
SCENARIØ: BASE CASE

Figure F-25

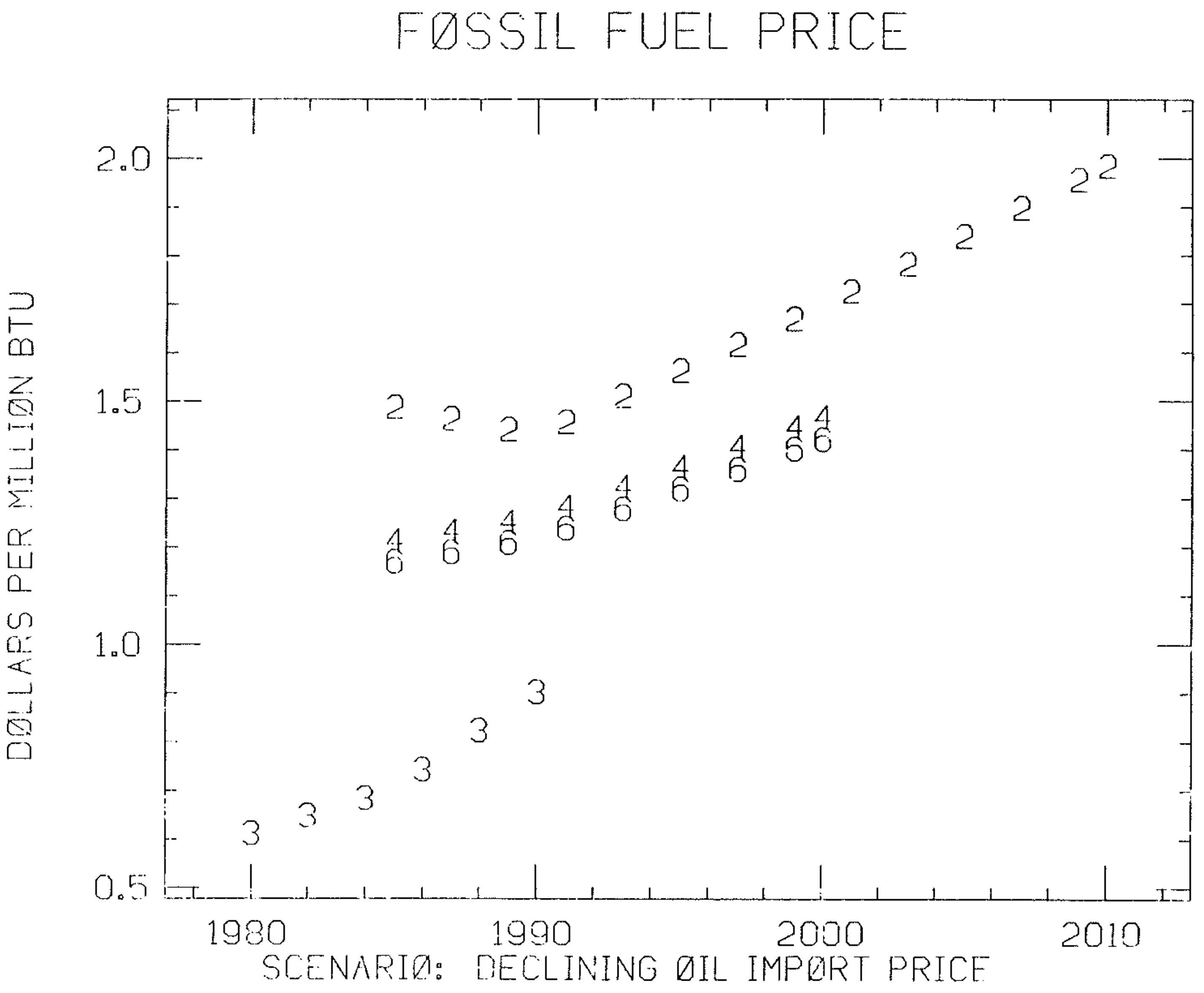

FØSSIL FUEL PRICE
DØLLARS PER MILLIØN BTU
2.0
1.5
1.0
0.5
1980
1990
2000
2010
SCENARIØ: DECLINING ØIL IMPØRT PRICE

Figure F-26

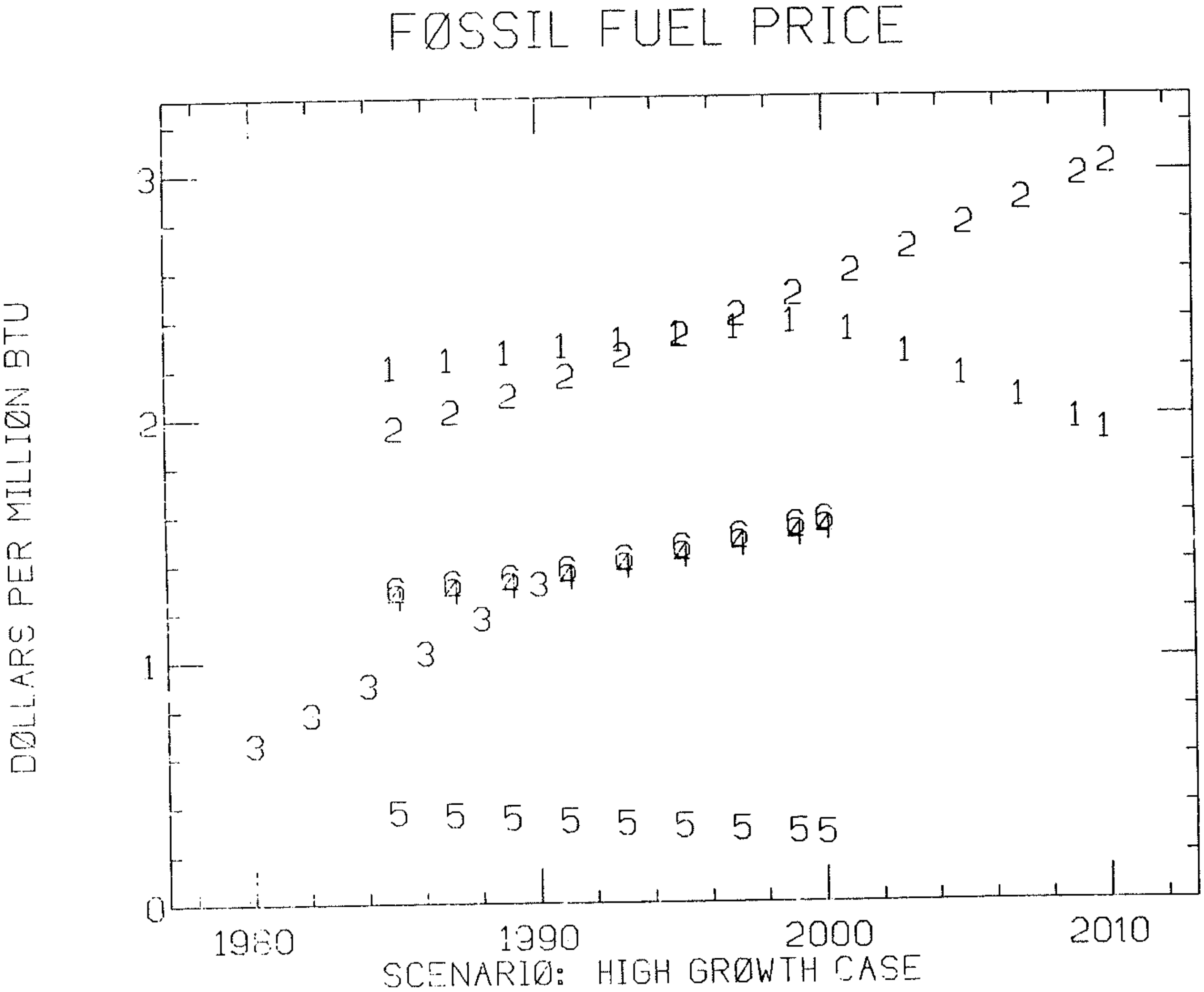

FØSSIL FUEL PRICE
DØLLARS PER MILLIØN BTU
0
1
2
3
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE
1
2
3
4
5
6

Figure F-27

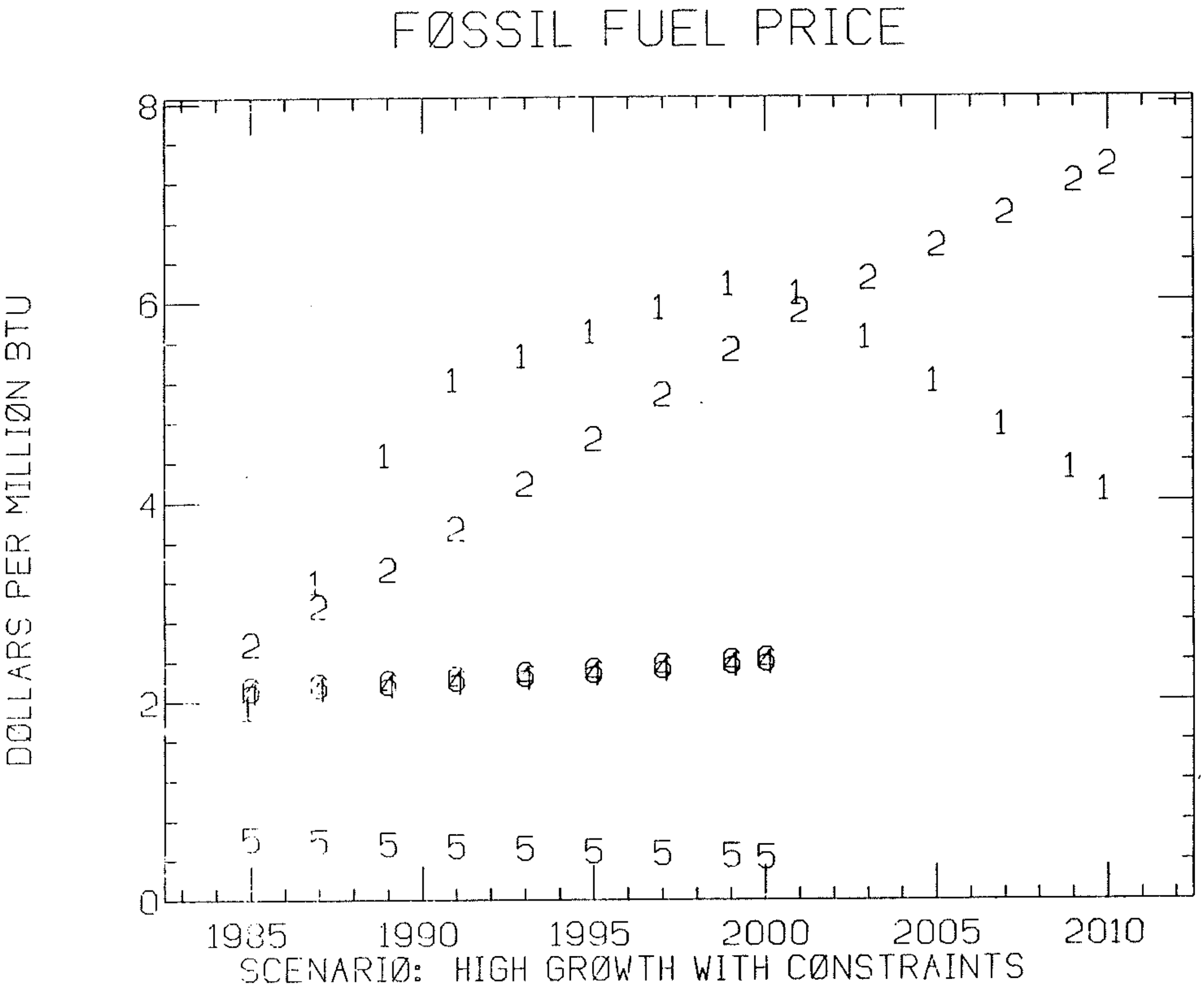

FOSSIL FUEL PRICE
DOLLARS PER MILLION BTU
0
2
4
6
8
1985
1990
1995
2000
2005
2010
SCENARIO: HIGH GROWTH WITH CONSTRAINTS
1
2
5
6

Figure F-28

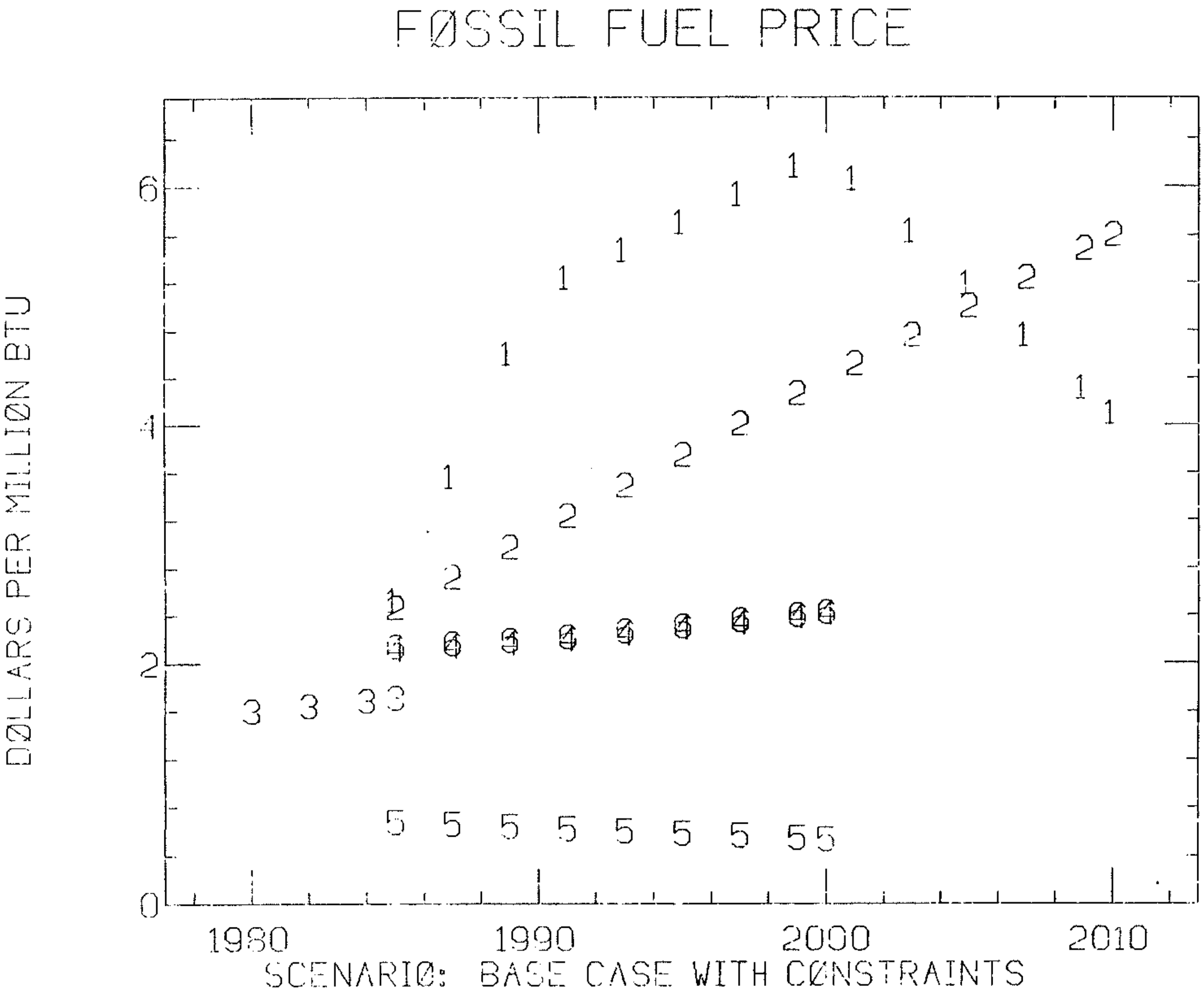

FØSSIL FUEL PRICE
DØLLARS PER MILLIØN BTU
0
2
4
6
1980
1990
2000
2010
SCENARIØ: BASE CASE WITH CØNSTRAINTS

Figure F-29

ENERGY CONSUMPTION PER CAPITA

This is defined as:

$$\frac{\text{TOTAL PRIMARY ENERGY INPUT (in quads)}}{\text{POPULATION (Census Series I or II, depending on the scenario)}}$$

and is reported in million Btu per person. It is a rough measure of how individual energy use is affected by changes in energy availability and the corresponding economic responses. The Base Case uses the Census medium growth (Series II) projections; the High Growth scenario uses the Census high growth (Series I) projections. (See the exceptions noted in Section 4 of this appendix for the Hnyilicza results.)

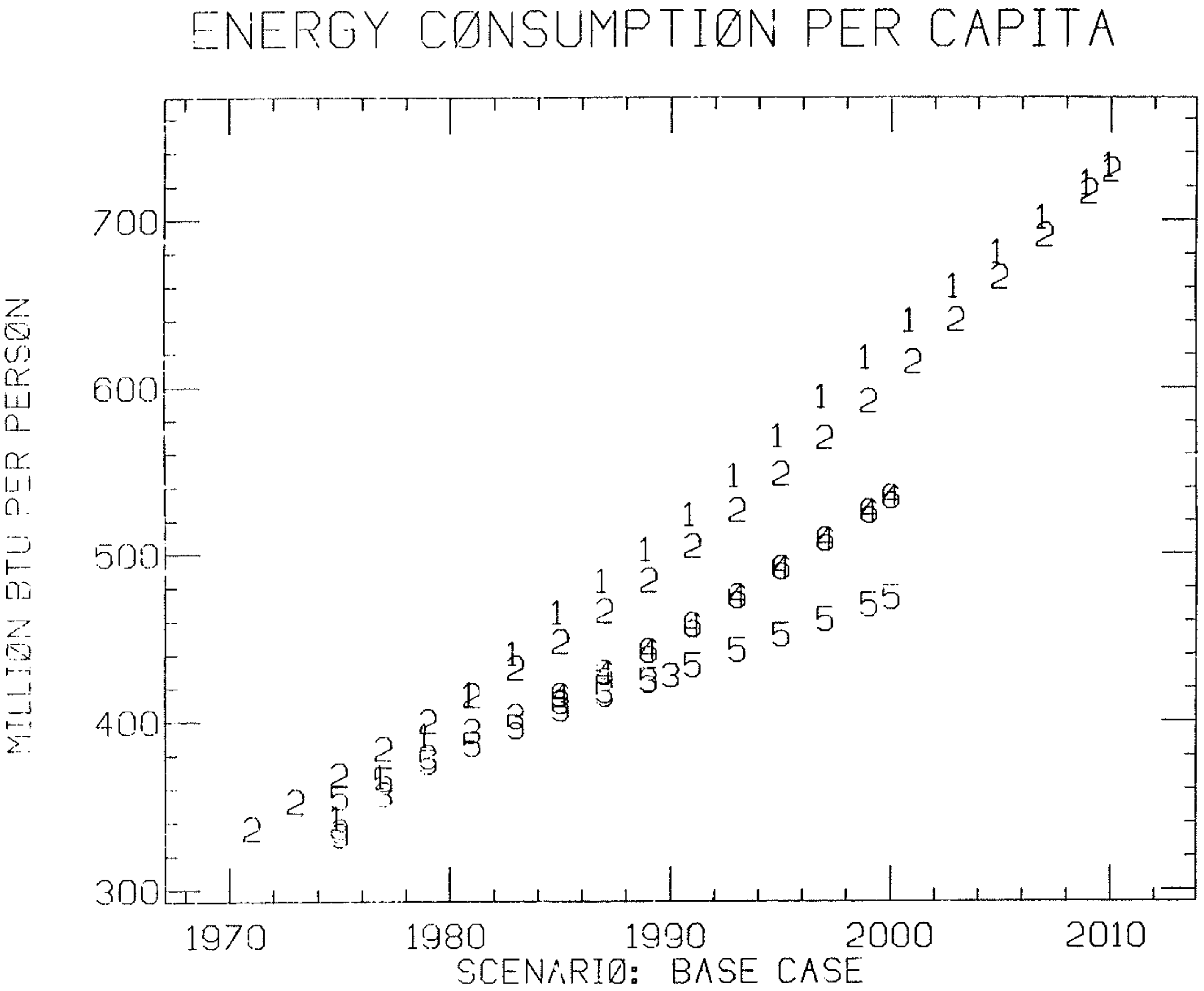

ENERGY CONSUMPTION PER CAPITA
MILLION BTU PER PERSON
700
600
500
400
300
1970
1980
1990
2000
2010
SCENARIO: BASE CASE
1
2
3
4
5
6

Figure F-30

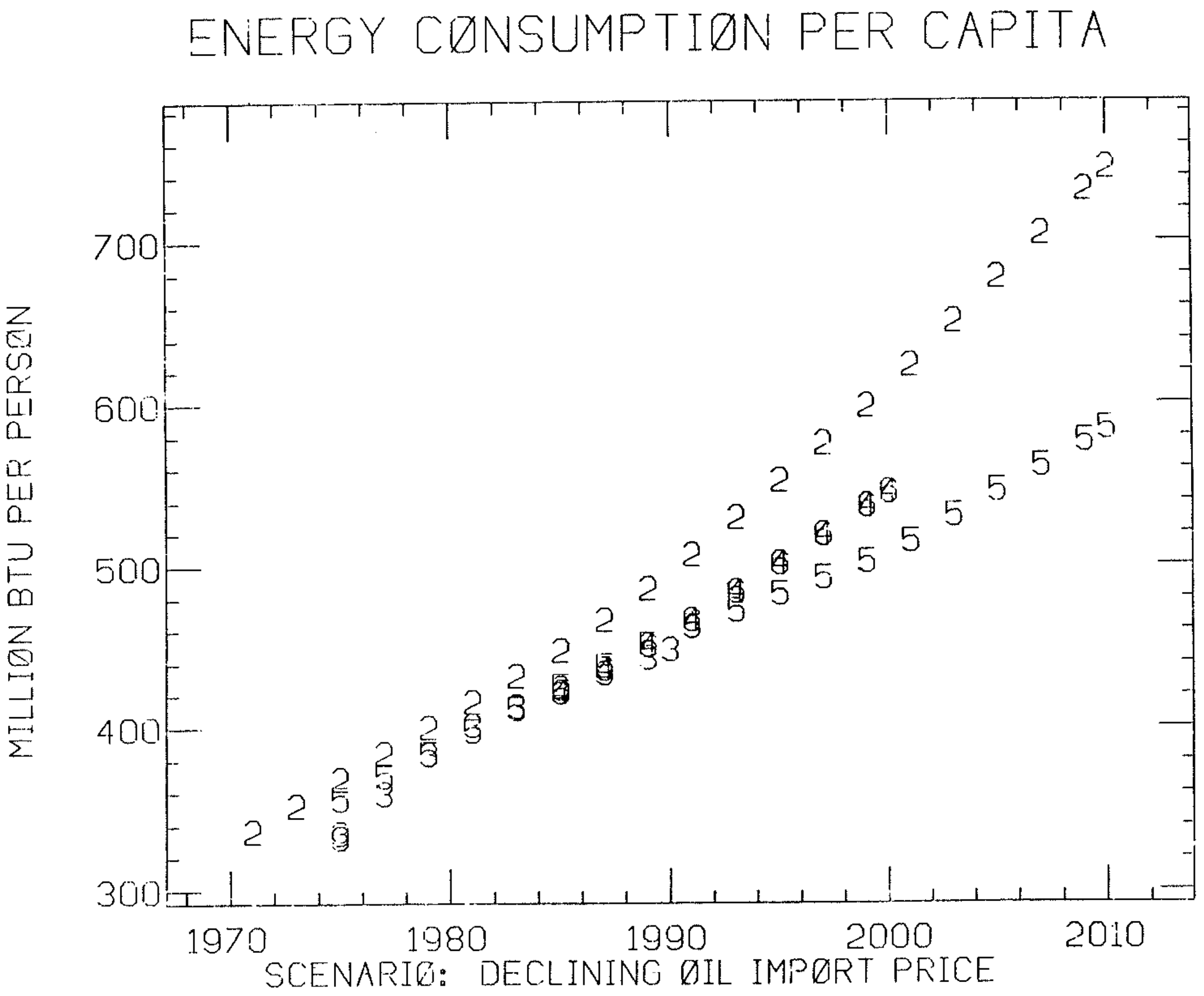

ENERGY CONSUMPTION PER CAPITA
MILLION BTU PER PERSON
700
600
500
400
300
1970
1980
1990
2000
2010
SCENARIO: DECLINING OIL IMPORT PRICE
2
3
5
6

Figure F-31

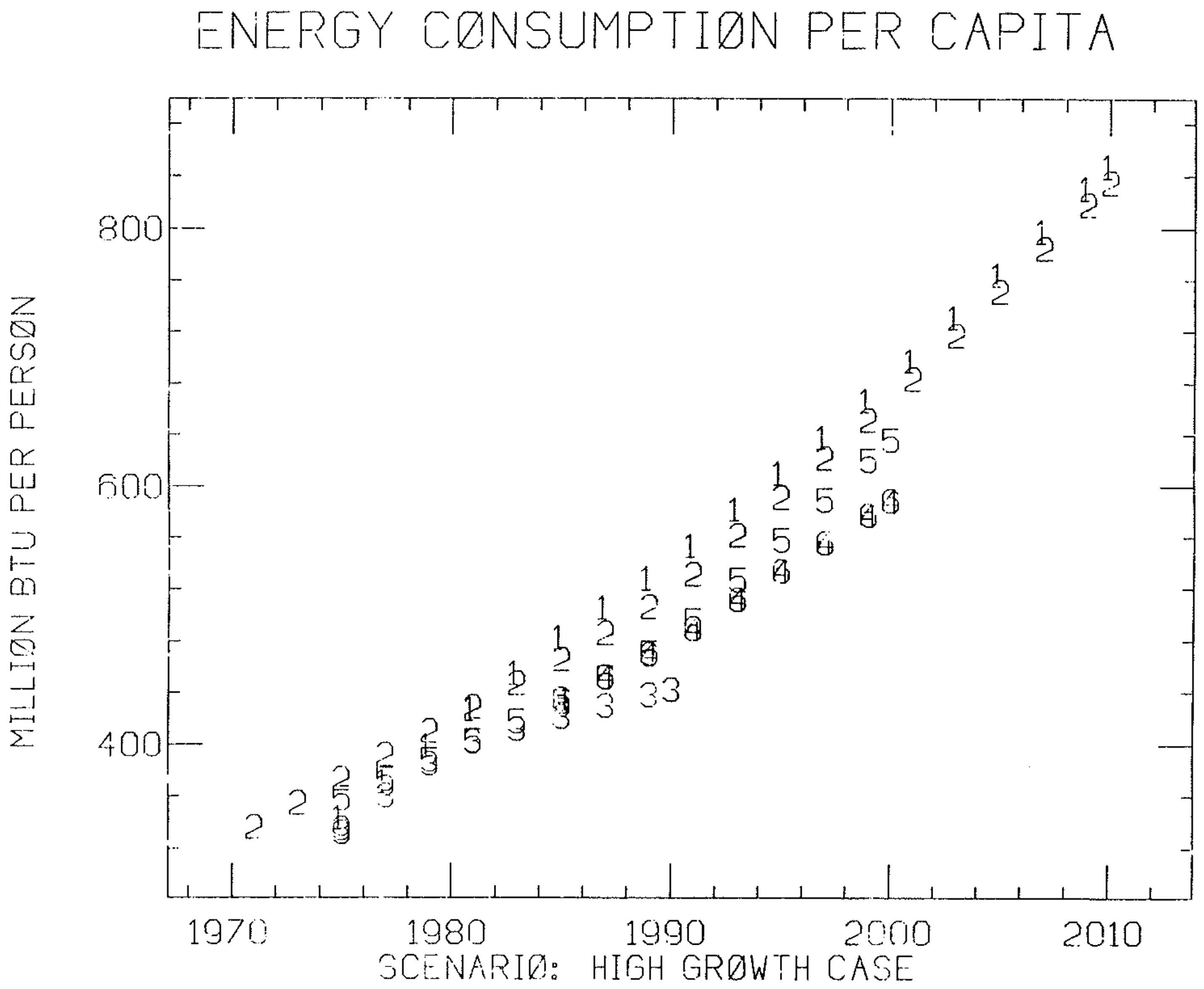

ENERGY CØNSUMPTIØN PER CAPITA
MILLIØN BTU PER PERSØN
800
600
400
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE
1
2
3
4
5
6

Figure F-32

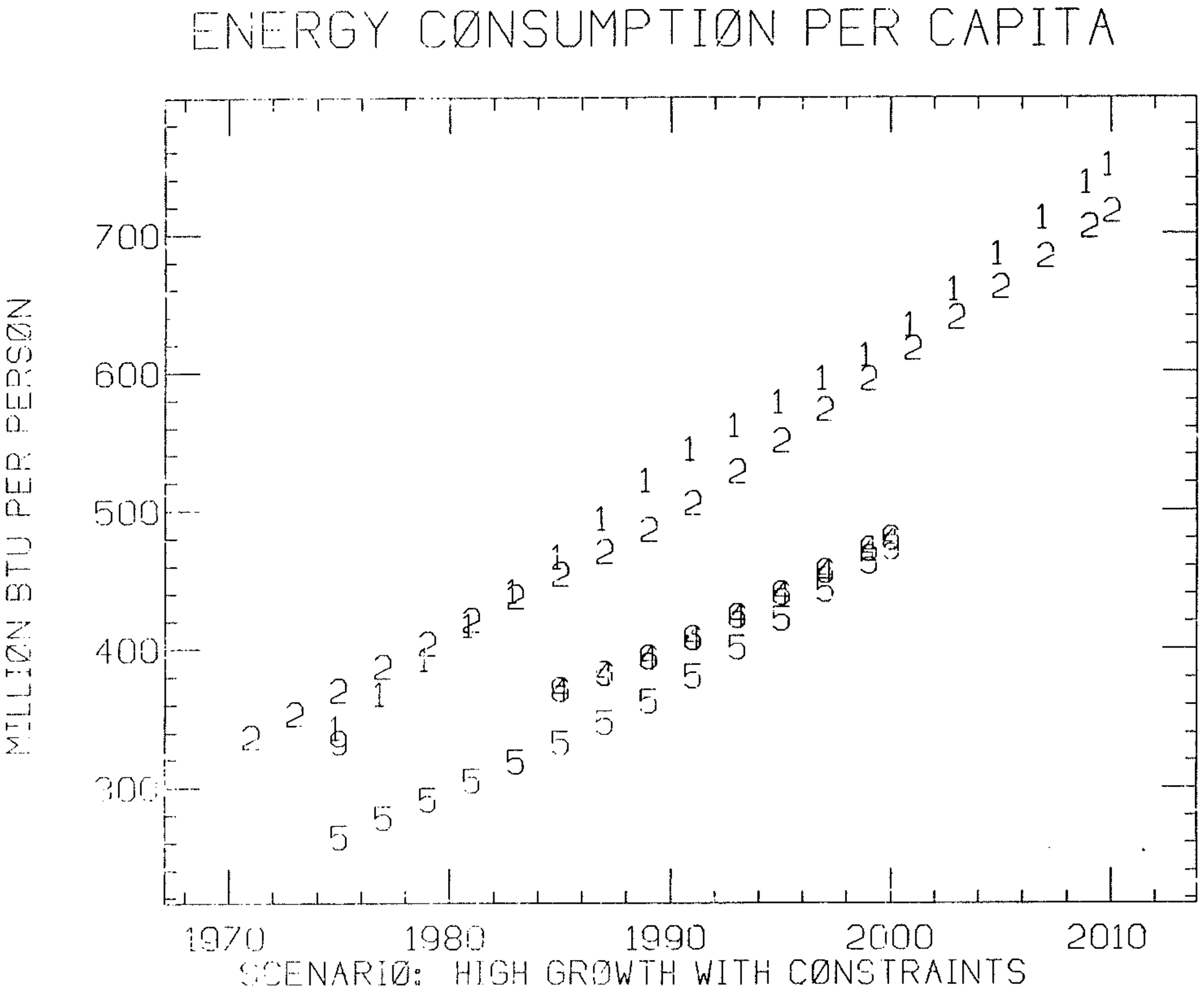

ENERGY CONSUMPTION PER CAPITA
MILLION BTU PER PERSON
700
600
500
400
300
1970
1980
1990
2000
2010
SCENARIO: HIGH GROWTH WITH CONSTRAINTS

Figure F-33

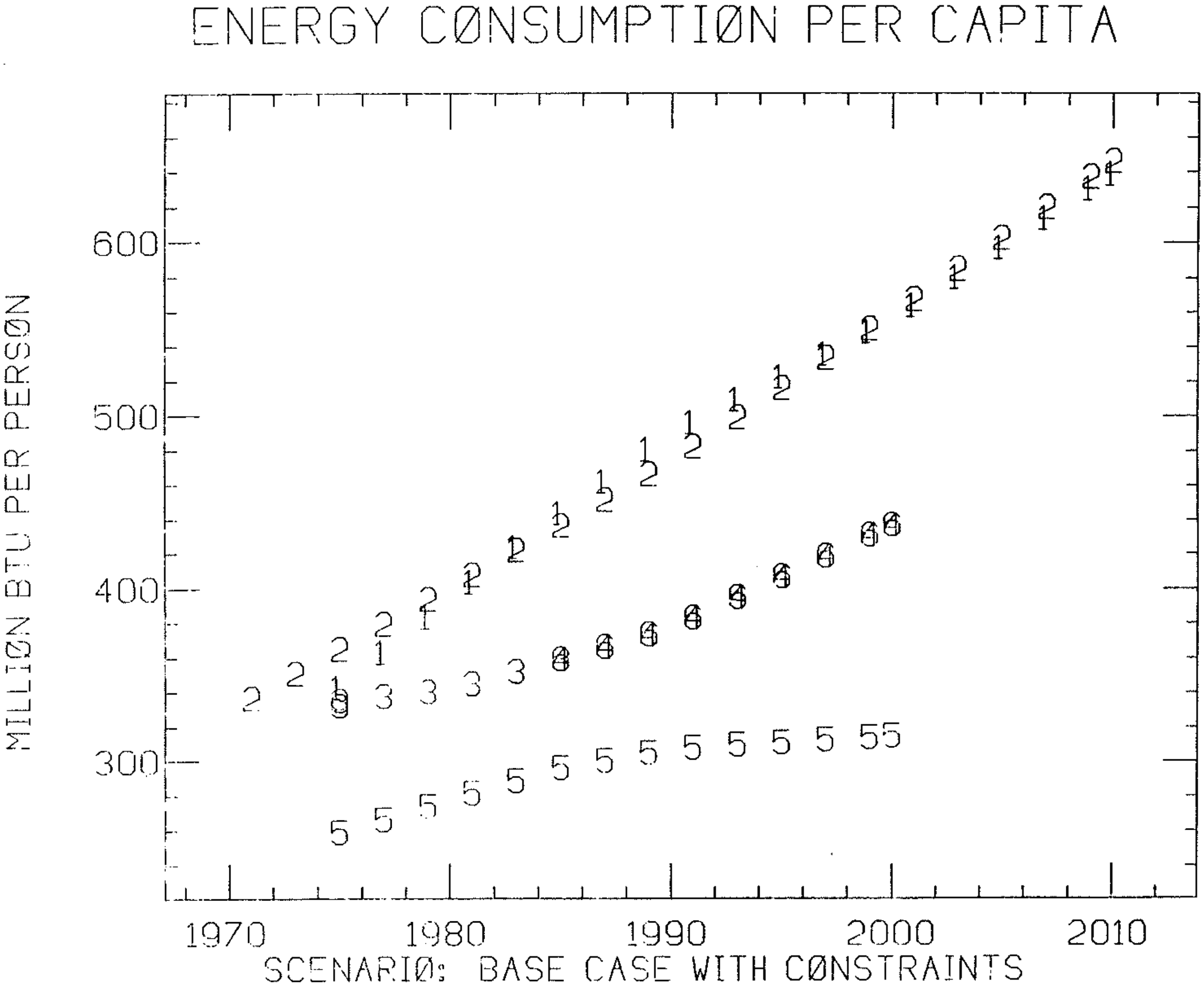

ENERGY CØNSUMPTIØN PER CAPITA
MILLIØN BTU PER PERSØN
600
500
400
300
1970
1980
1990
2000
2010
SCENARIØ: BASE CASE WITH CØNSTRAINTS

Figure F-34

ENERGY-GNP RATIO RANGE

This is a cross-scenario measure, defined for each model as:

$$\frac{\text{MAX (Energy-GNP Ratio)} - \text{MIN (Energy-GNP Ratio)}}{\text{Base Case Energy-GNP Ratio}}$$

This statistic is intended to highlight models with large potential variability and flexibility as those with limited changes in energy use and economic activity.

The large range for the results of Hnyilicza are established by Scenario 2, the Declining Oil Import Case. This scenario was not investigated extensively by the group. If this scenario is deleted, the range for Hnyilicza's model is cut in half and his results are closer to those of the other models with similar aggregate elasticities of substitution.

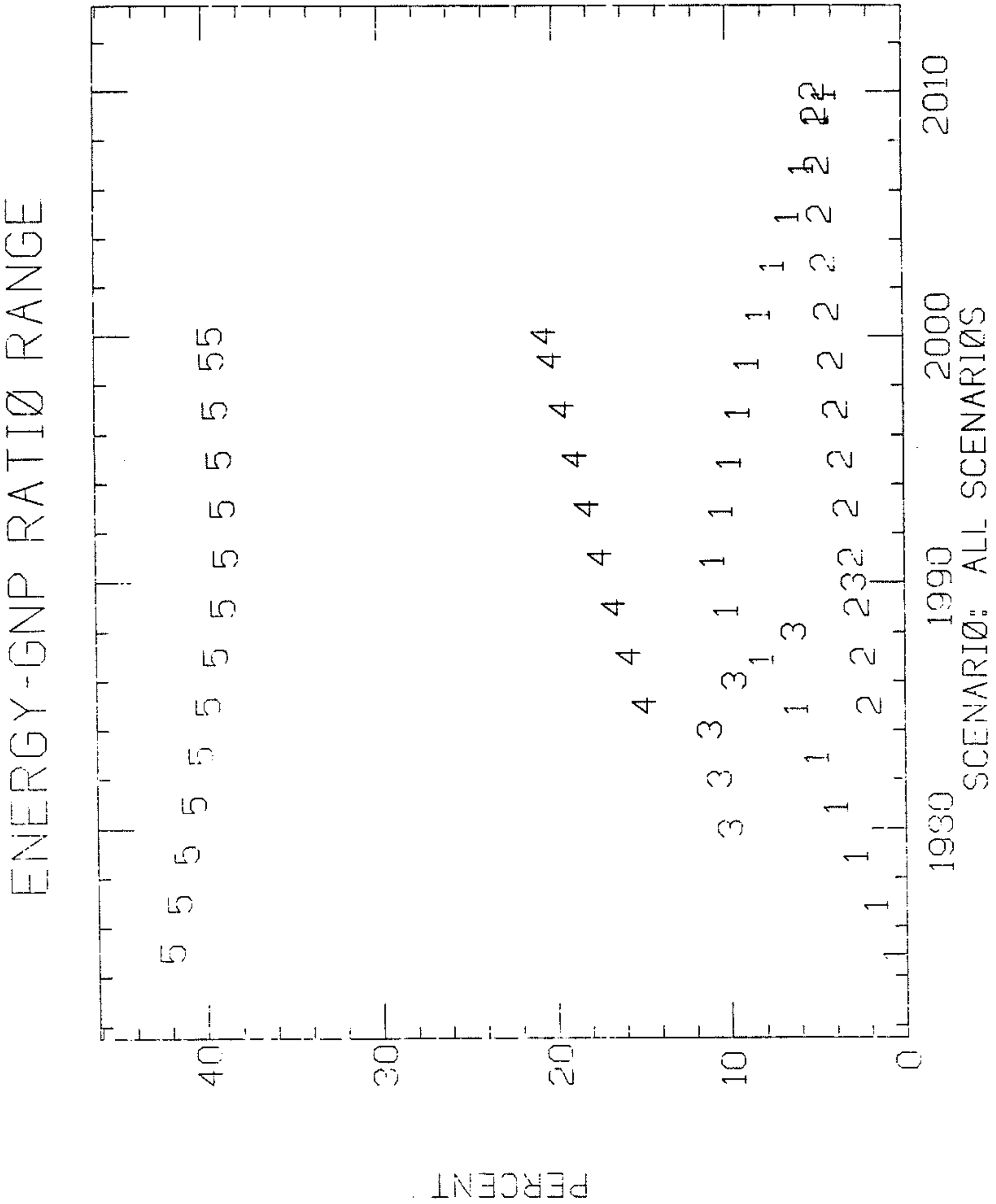

ENERGY-GNP RATIO RANGE
PERCENT
0
10
20
30
40
1980
1990
2000
2010
SCENARIO: ALL SCENARIOS
1
2
3
4
5

Figure F-35

GNP EFFECTS OF CONSTRAINTS

This is reported for both the Base Case and the High Growth Case and is defined as:

- $\frac{\text{GNP (Base Case with Constraints)}}{\text{GNP (Base Case)}}$
- $\frac{\text{GNP (High Growth Case with Constraints)}}{\text{GNP (High Growth Case)}}$

For individual models, the graph displays the relative effects on GNP of energy constraints or higher energy prices. This measure is not as good a cross-model comparison as intended. Unfortunately, the method for implementing the energy constraints varies significantly across models. For example, the use of taxes in the Kennedy-Niemeyer model has little impact because there is no substitution (by assumption) and, therefore, the taxes produce no reduction in energy use and little GNP effect. In contrast, PILOT enforces a direct reduction in energy use with a corresponding reduction in GNP. But with the same energy input, these two models would produce similar results. This deficiency in scenario design was noted after implementation of the tests, and could not be corrected. It indicates, however, that the comparison of elasticities of substitution is the more informative measure of the models' link between energy and the economy.

The results from Hnyilicza's model are caused by a significant reduction in capital accumulation in the presence of higher energy prices. This model result is discussed in further detail in the explanation of the comparison with the Elephant-Rabbit predictions.

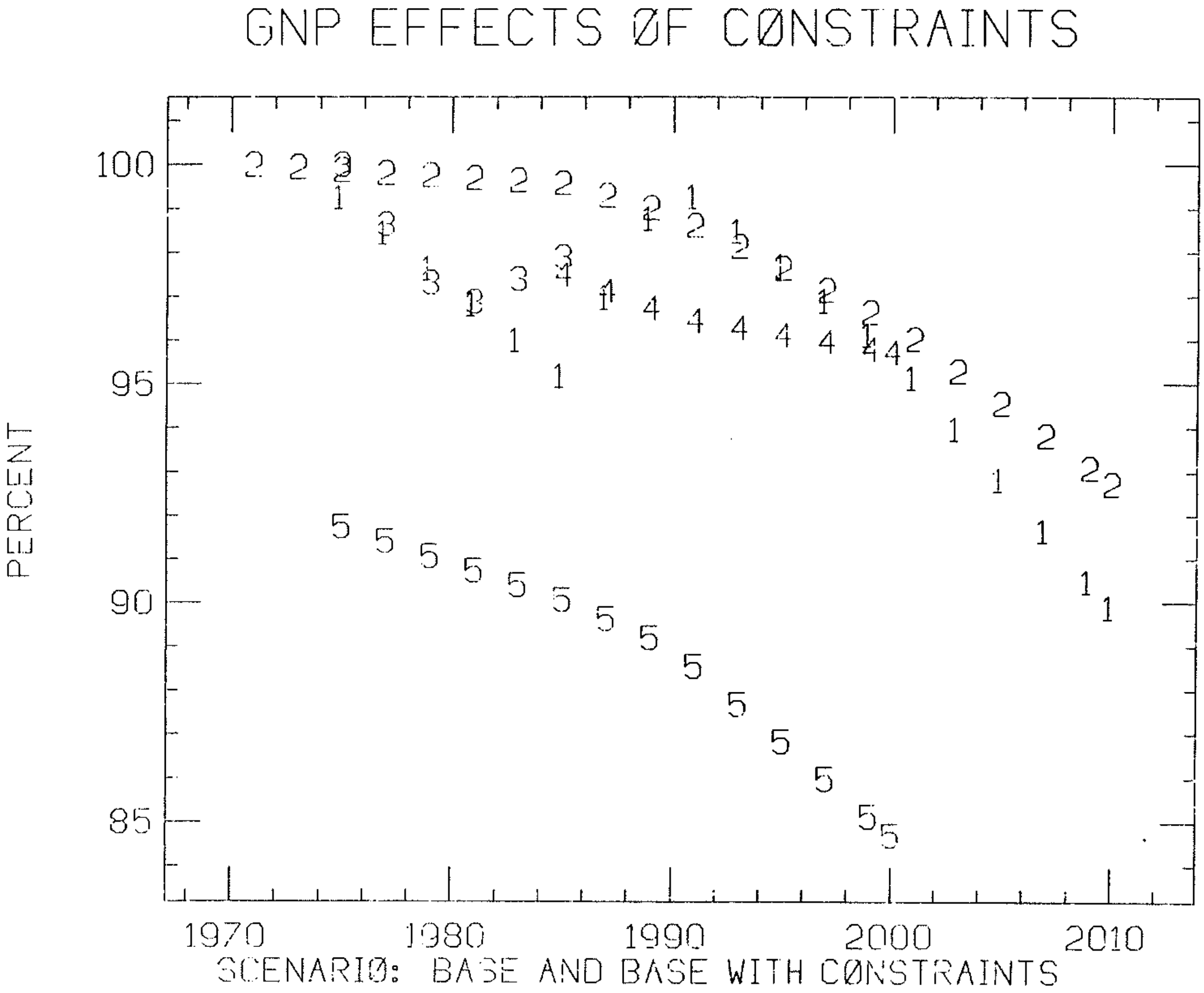

GNP EFFECTS ØF CØNSTRAINTS
PERCENT
100
95
90
85
1970
1980
1990
2000
2010
SCENARIØ: BASE AND BASE WITH CØNSTRAINTS

Figure F-36

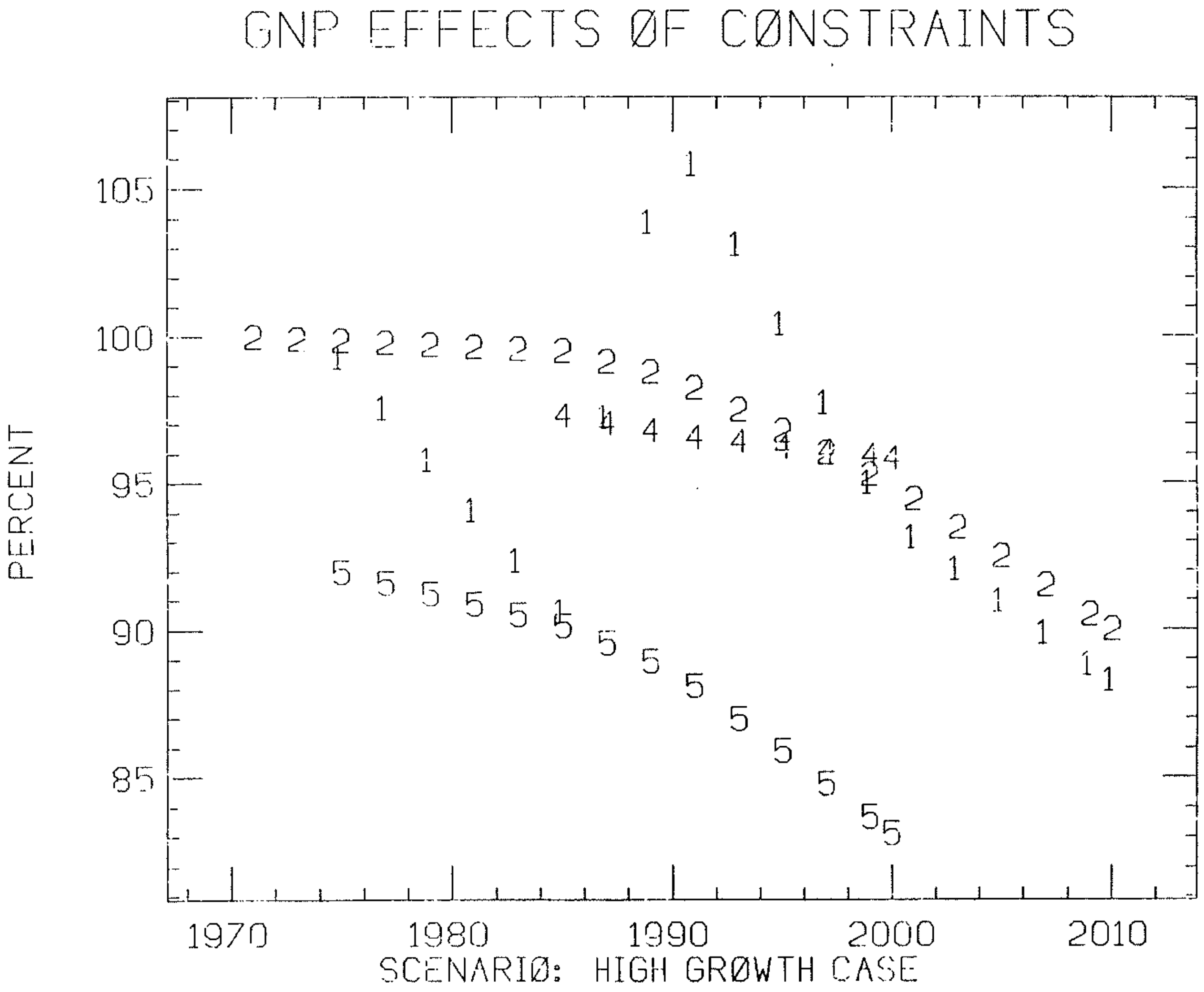

GNP EFFECTS ØF CØNSTRAINTS
PERCENT
105
100
95
90
85
1970
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE
1
2
4
5

Figure F-37

ENERGY IMPACTS OF ECONOMIC GROWTH

This comparison plots two points for each model in terms of GNP and energy. The lower point is the result from the Base Case, the upper point is the High Growth scenario. The two points are connected by a linear interpolation.

The purpose of this comparison is to illustrate the effects of the economy on the energy sector. The primary focus of the EMF study is the feedback in the models, i.e., the effect on the economy of changes in energy prices or availability. The central issue is the degree of flexibility exhibited by the economy to substitute other factors of production for the higher priced energy. But this flexibility should not be confused with the direct effects of the economy on energy demand. In the presence of stable energy prices, increases in economic activity should produce corresponding increases in energy demand. Hence, the comparison of the Base Case and High Growth scenarios here should show upward sloping relationship. We see that all the models possess this desirable property and produce similar results.

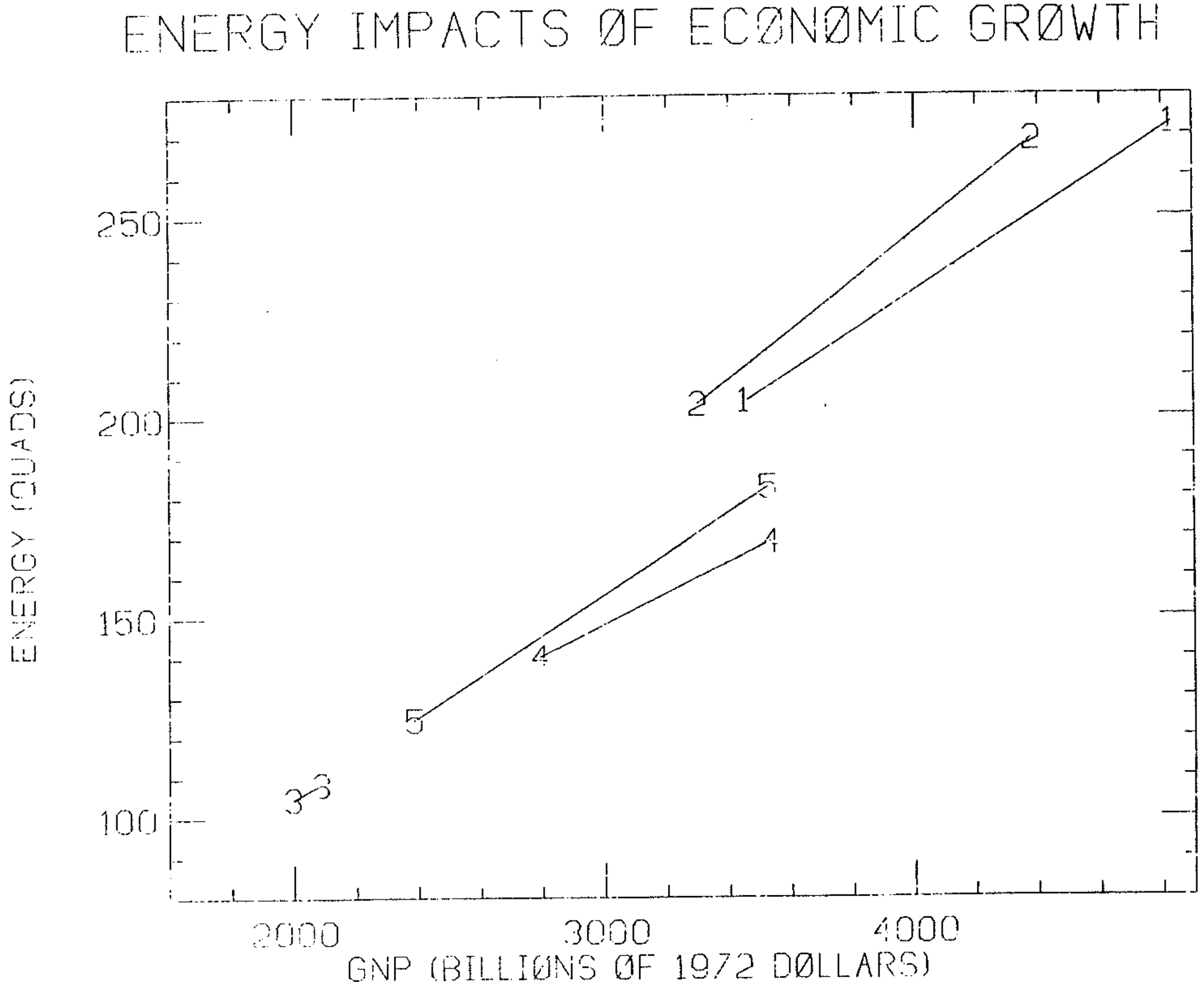

ENERGY IMPACTS ØF ECØNØMIC GRØWTH
ENERGY (QUADS)
250
200
150
100
2000
3000
4000
GNP (BILLIØNS ØF 1972 DØLLARS)
1
1
2
2
5
5
4
4
3
3

Figure F-38

IMPLIED INCOME ELASTICITY

The focus of the EMF comparison is on the economic effects of changed energy availability. This should not be confused with the impact of economic activity on the energy sector. In the presence of constant energy prices, higher levels of economic activity, such as through higher levels of employment, should increase energy demand. All the models share this property as illustrated by the graph on page F-77. One measure of the strength of this link is found in the implied income elasticity per capita and is defined as:

$$\eta = \frac{\delta \ln \text{ (Energy per capita)}}{\delta \ln \text{ (GNP per capita)}} .$$

This is measured here by comparing the Base Case and High Growth scenarios for each model.

$$\eta = \frac{\ln\left(E_2/Pop_2\right) - \ln\left(E_1/Pop_1\right)}{\ln\left(GNP_2/Pop_2\right) - \ln\left(GNP_1/Pop_1\right)}$$

where E = Total Energy
Pop = Population
GNP = Gross National Product
1 = Base Case Scenario
2 = High Growth Scenario

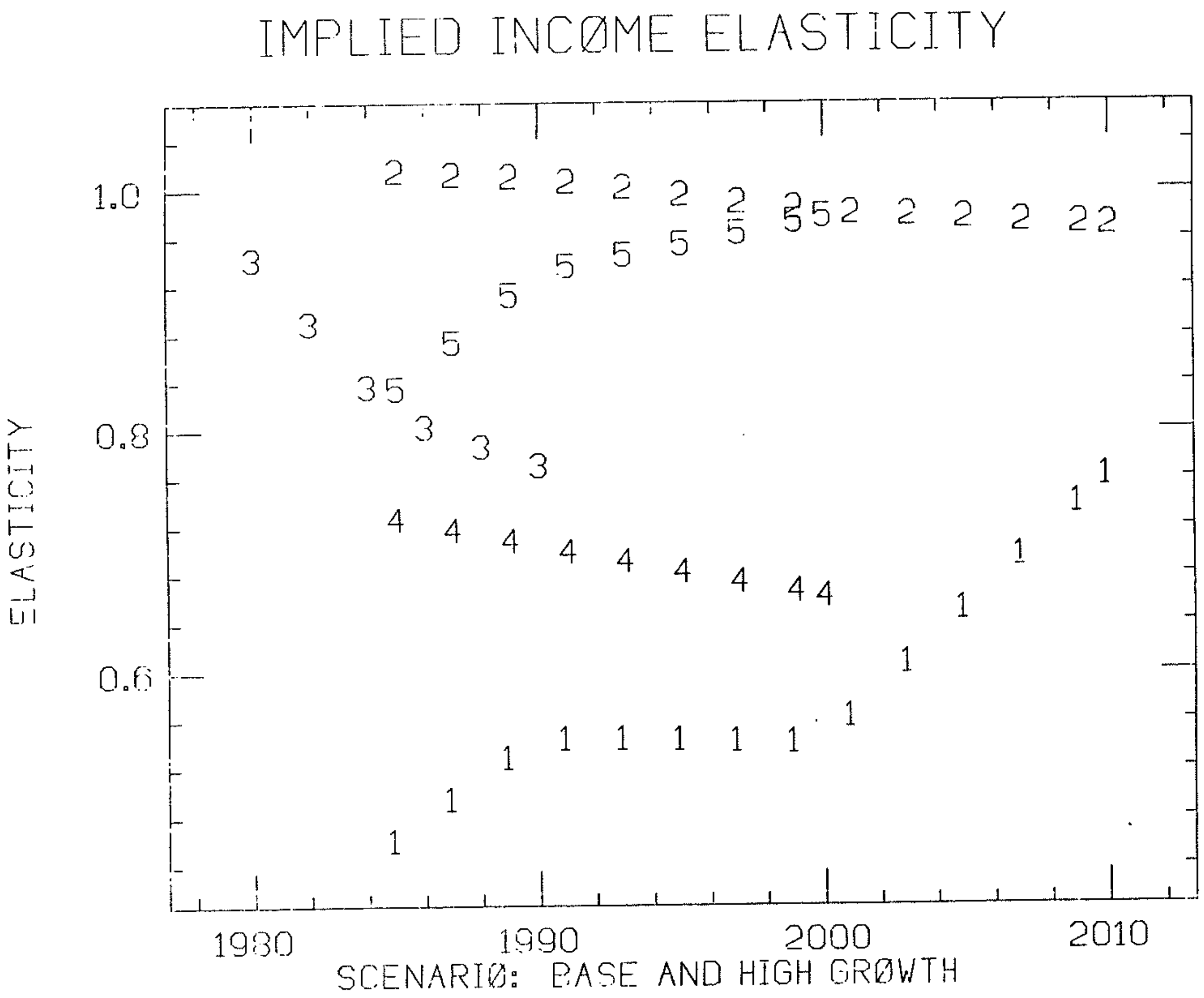

IMPLIED INCØME ELASTICITY
ELASTICITY
1.0
0.8
0.6
1980
1990
2000
2010
SCENARIØ: BASE AND HIGH GRØWTH
1
2
3
4
5

Figure F-39

ELASTICITY OF SUBSTITUTION

The elasticity of substitution is the most important statistic developed by the EMF for comparison of the different models' link between energy and the economy. The structure of the approximation and the crucial nature of the elasticity of substitution are developed in detail in Appendix B. The simple model found there assumes that the long run total nonenergy output of the economy can be approximated by a constant elasticity of substitution production function with inputs of energy and all other factors. With two explicit assumptions, the data from scenarios 1-5, and 3-4 can be used to estimate the elasticity of substitution embedded in the detailed models participating in the EMF study.

These assumptions are:

- The marginal productivity of energy in the detailed models is approximated by the derivatives of the constant elasticity production function.
- The scenarios with energy constraints or higher energy prices are equivalent to the imposition of a long run primary energy Btu tax that is redistributed to consumers.

With these assumptions, the elasticity of substitution is obtained as:

$$\sigma = - \frac{\ln \left(E_1 Y_2 / Y_1 E_2 \right)}{\ln \left(P_1 / P_2 \right)}$$

where $Y_1 = P_1 E_1 + GNP_1$

$Y_2 = P_1 E_2 + GNP_2$

E = Total Energy Input

P = Fossil Fuel Price of Energy

Y = Total Output

- 1 = Base Case
  2 = Base Case with Energy Constraints
- 1 = High Growth Case
  2 = High Growth Case with Energy Constraints

In computing the elasticity of substitution for the Hudson-Jorgenson and the DRI-Brookhaven models, an ad hoc correction has been made. These models imposed the higher energy prices by adding a $1 Btu tax to delivered energy, in particular, to delivered electricity. But our assumptions imply the tax is on the fuels used for electricity. This would make a difference of a factor of 3.0 in the magnitude of the primary energy tax. The ad hoc correction approximates the energy level which would occur if the tax were placed on all primary energy. This increases the long run elasticity estimate from 0.35 to 0.49. The higher figure should be an overestimate of the true elasticity embedded in the models. The details of this correction are found in the attached Technical Memo EMF-TM-77-1.5.

SUBJECT: CORRECTION OF ELASTICITY ESTIMATES IN HUDSON-JORGENSON RESULTS
AUTHOR: William W. Hogan

EMF TECHNICAL MEMO-77-1.5
DATE: 5/31/77

Notation: Subscripts 1 and 2 refer to the base case and base case with tax; P, the price of energy; E, the primary energy input; x, the portion of the input for nonelectric purposes; and y = E-x.

Normally, we follow the Elephant-Rabbit paradigm and (assuming all taxes are rebated) define,

$$Y_i = GNP_i + P_1E_i \qquad i = 1,2.$$

Then,

$$\sigma = -\ln(E_1Y_2/Y_1E_2)/\ln(P_1/P_2) \quad .$$

This assumes the tax is imposed on primary energy input. But the Hudson-Jorgenson model set the tax on delivered energy. Hence, electricity is overrepresented in E and this biases the calculation of σ.

There are a number of reasonable adjustments to propose to correct for this bias. I recommend the following:

To first order, the GNP should remain constant if the delivered energy remains constant. As we raise the price of delivered electricity (from $1.00/10^6 Btu tax to $3.00/10^6 Btu to correct for efficiency) there will be a reduction in electricity demand and an increase in nonelectric demand. If delivered energy remains constant, this produces a 2 quad drop in E for each end use quad shifted. If we further assume that this shift continues until the reductions in x and y are proportionally equal, we have a means for obtaining a corrected estimate of σ.

The bias in the resulting calculation of total energy could go either way, but should be small. The bias in the GNP is positive and thereby overstates σ, but I think the error should be small there too.

Hence, for x_i, y_i, I propose to calculate a shift from electric to nonelectric of Δ such that

$$\frac{x_2 + 1/3\Delta}{x_1} = \frac{y_2 - \Delta}{y_1}, \quad \text{therefore} \qquad \Delta = \frac{x_1y_2 - y_1x_2}{x_1 + 1/3y_1}$$

Then let $\hat{E}_2 = E_2 - 2/3\Delta$ and use $\hat{E}_2$ in the place of E_2 to calculate σ, but with the same assumption on the primary price of energy (where we use the average fossil fuel price).

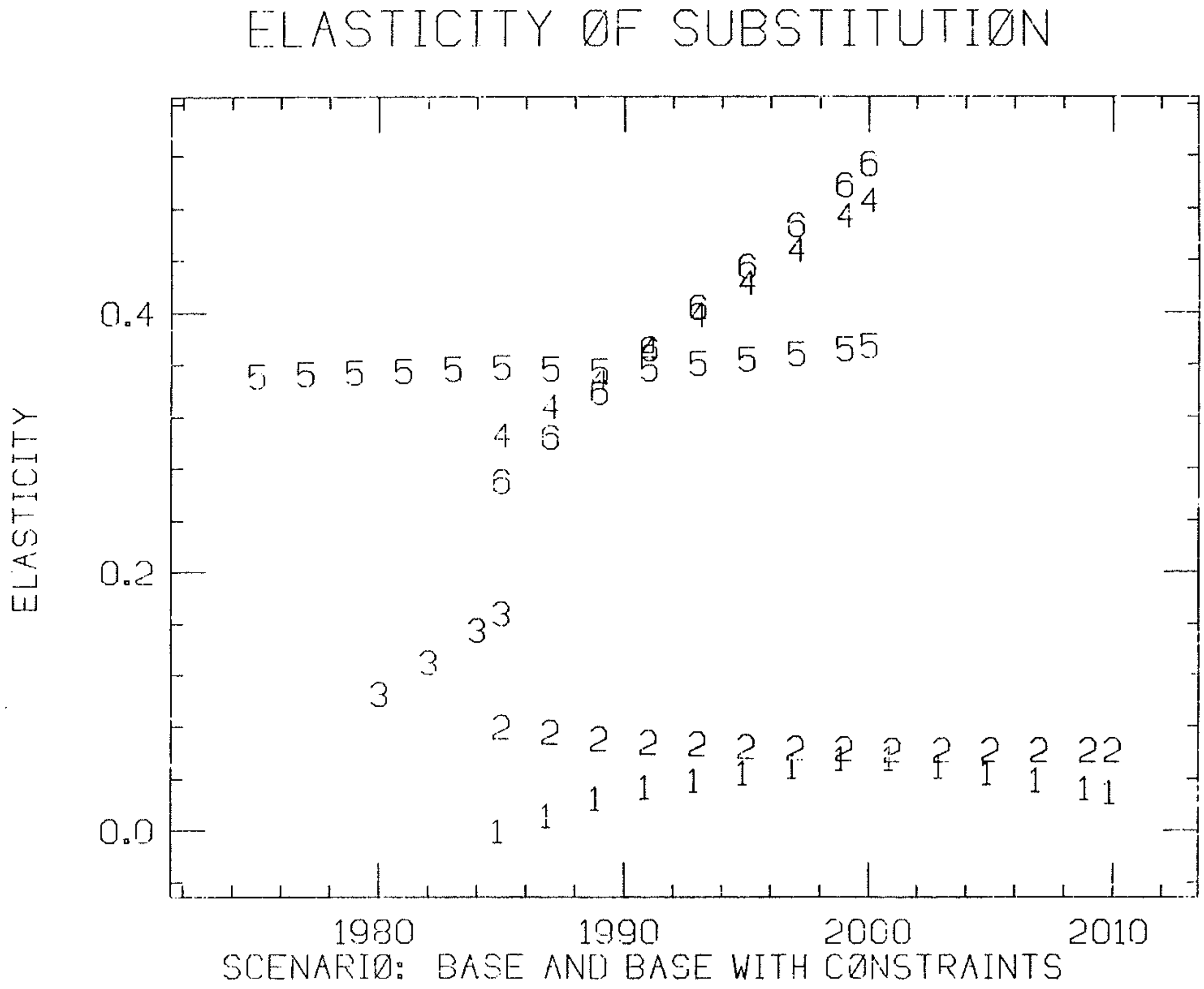

ELASTICITY ØF SUBSTITUTIØN
ELASTICITY
0.4
0.2
0.0
1980
1990
2000
2010
SCENARIØ: BASE AND BASE WITH CØNSTRAINTS

Figure F-40

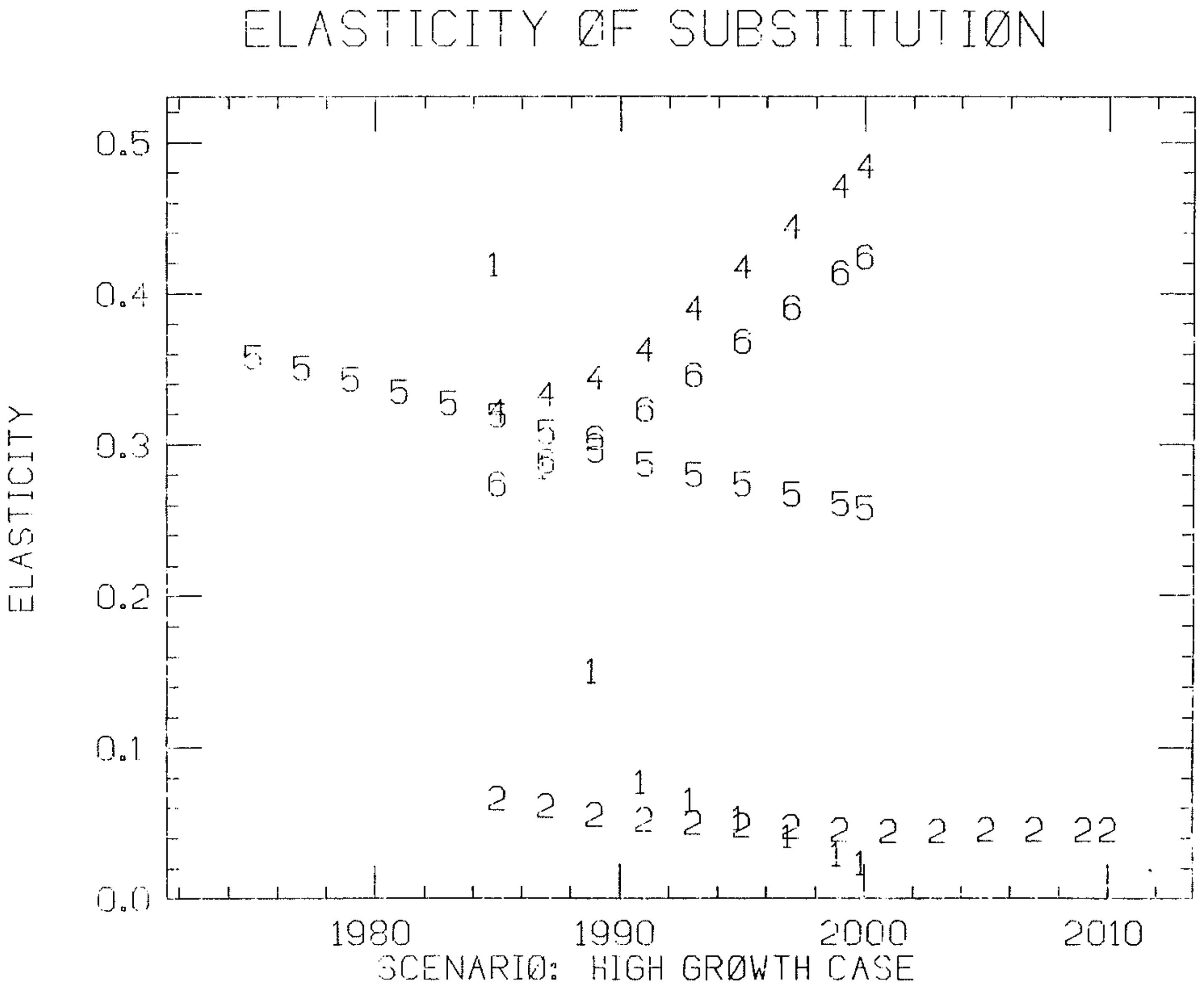

ELASTICITY ØF SUBSTITUTIØN
ELASTICITY
0.5
0.4
0.3
0.2
0.1
0.0
1980
1990
2000
2010
SCENARIØ: HIGH GRØWTH CASE

Figure F-41

ELEPHANT-RABBIT COMPARISON

The main body of this report and the comparison of the models rely heavily on the highly stylized view of the world found in the simple two factor Elephant-Rabbit model as presented in Appendix B. The appeal of this model is found in its simplicity and the transparent role of the value share and elasticity of substitution in determining the link between the energy sector and the remainder of the economy. The value of the simplification rests in part on the degree of faithfulness in representing the detailed models when examining the same relationship. The detailed models can address many questions, but the simple model can address only one, the link between total energy and the total economy. In these graphs, we compare the results of the Elephant-Rabbit model to those of the detailed systems in addressing the impact of a higher price for all primary energy.

Using the implied elasticity of substitution for each model, the actual reduction of GNP for the Tax Scenario vs the Base Case is shown along with two predictions based on the simple approximation developed in Appendix B.

The upper line in each case is the prediction obtained by assuming that capital and labor remain constant but energy use is reduced. The lower line results from holding labor constant and allowing capital to change so as to hold its marginal productivity constant.

In all cases but one, the experiment with constant marginal productivity of capital produces a good approximation to the aggregate results of detailed models. The one exception is for the comparison of Hnyilicza's output. This anomoly has not been resolved, but one test was conducted to identify the source of the deviation.

The structure of Hnyilicza's model permits control over the accumulation of capital and wealth before implementing the Btu tax. A test scenario with the same capital and wealth inputs as the Base Case but the energy tax in the year 2000 only was conducted. This produced a drop in energy input of 6.1% and GNP of only 3.2%, in closer agreement with the predictions of the simple Elephant-Rabbit model. The apparent failure of the simple model is in capturing the more complex dynamic relations in Hnyilicza's system.

SUBJECT: SPECIAL TAX SCENARIO WITH HNYILICZA'S MODEL EMF TECHNICAL MEMO-77-1.4

AUTHOR: William W. Hogan DATE: 5/31/77

Hnyilicza's model is the only system with GNP reductions from the Btu tax differing substantially from the aggregate predictions of the simple framework developed in the Elephant-Rabbit model. This anomoly has not been resolved fully, but one special scenario offers some insight as to the possible cause of the difference.

All the Btu tax or energy constraint scenarios assume the tax exists over a number of years, long enough for the full effect of the tax to work through the system. In Hnyilicza's model, all dynamic effects are captured by changes in capital accumulation and wealth, but for a fixed level of capital and wealth input the remainder of the model adjusts to the long run equilibrium each year. This property of the model permits a simple test of the response to energy taxes if all capital investment is held constant. We impose the tax in the target year only. The capital and wealth input is then the same as the base case, and the long run response to the direct changes in energy is revealed.

This special scenario was implemented by Hnyilicza with his model. The results for the year 2000 are shown in Table 1.

Table 1
HNYILICZA SPECIAL SCENARIO
ECONOMIC IMPACT IN YEAR 2000

	Base Case	Tax in All Years	Tax in 2000 Only
GNP (1958 $)	1576.00	1335.00	1526.00
Energy Input (Quads)	124.30	82.75	107.30
Price of Primary Energy ($58/$10^6$ Btu)	.19	.36	.29
Capital in Energy Sector (INDEX)	26.15	22.22	26.15
Capital in Nonenergy Sector (INDEX)	34.67	29.80	34.67
Implied Elasticity of Substitution Relative to Base Case		-.37	-.27

These results indicate that the source of the deviation in the actual results versus the simple forecast must be found in the more complex dynamic effects on capital formation. When capital formation is held constant, the aggregate results of Hnyilicza's model conform closely to the prediction of the simpler framework with the appropriate elasticity of substitution.

Further note that when capital is permitted to adjust endogenously, the reduction in capital input matches the reduction in output.

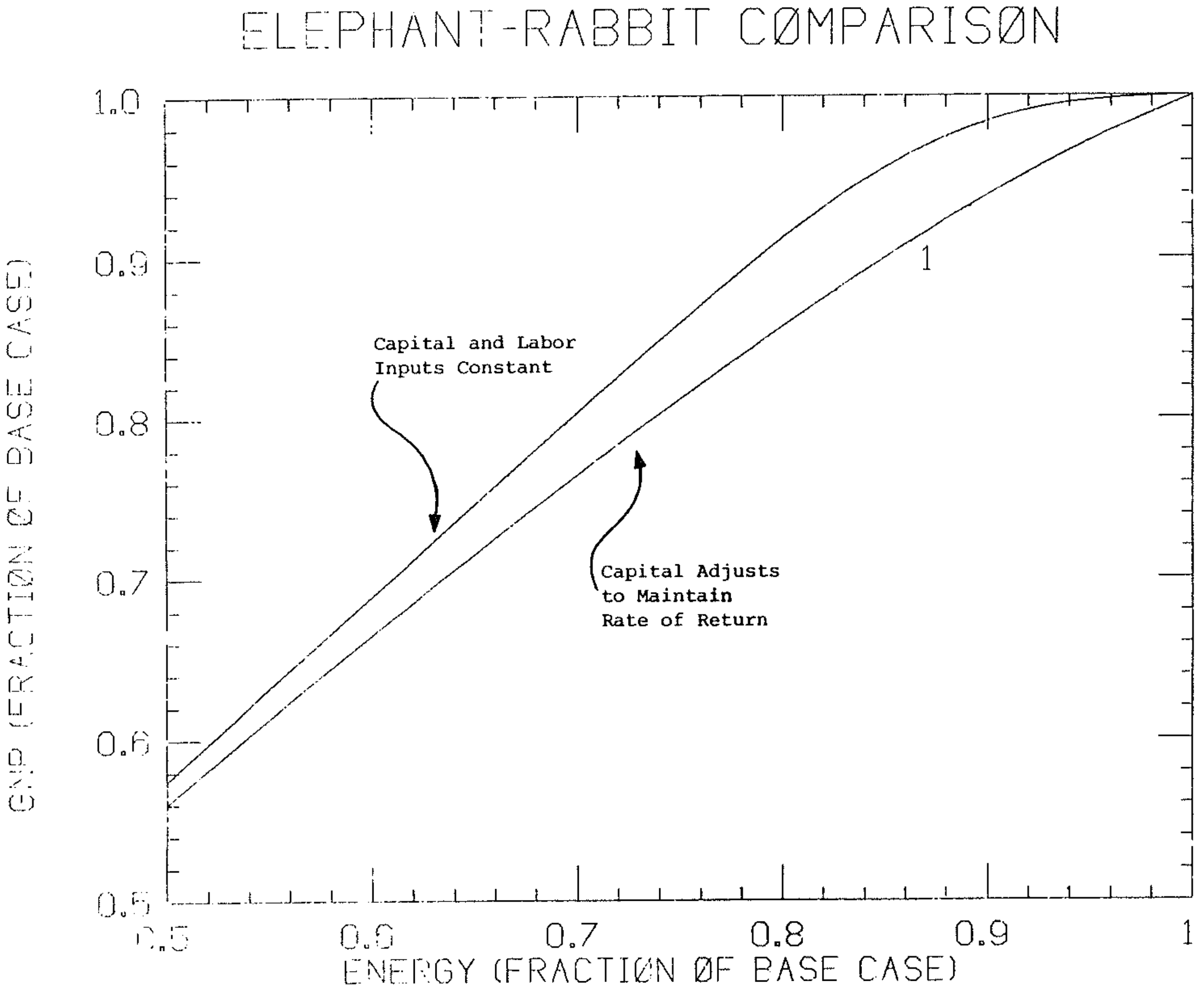


Figure F-42. PILOT MODEL

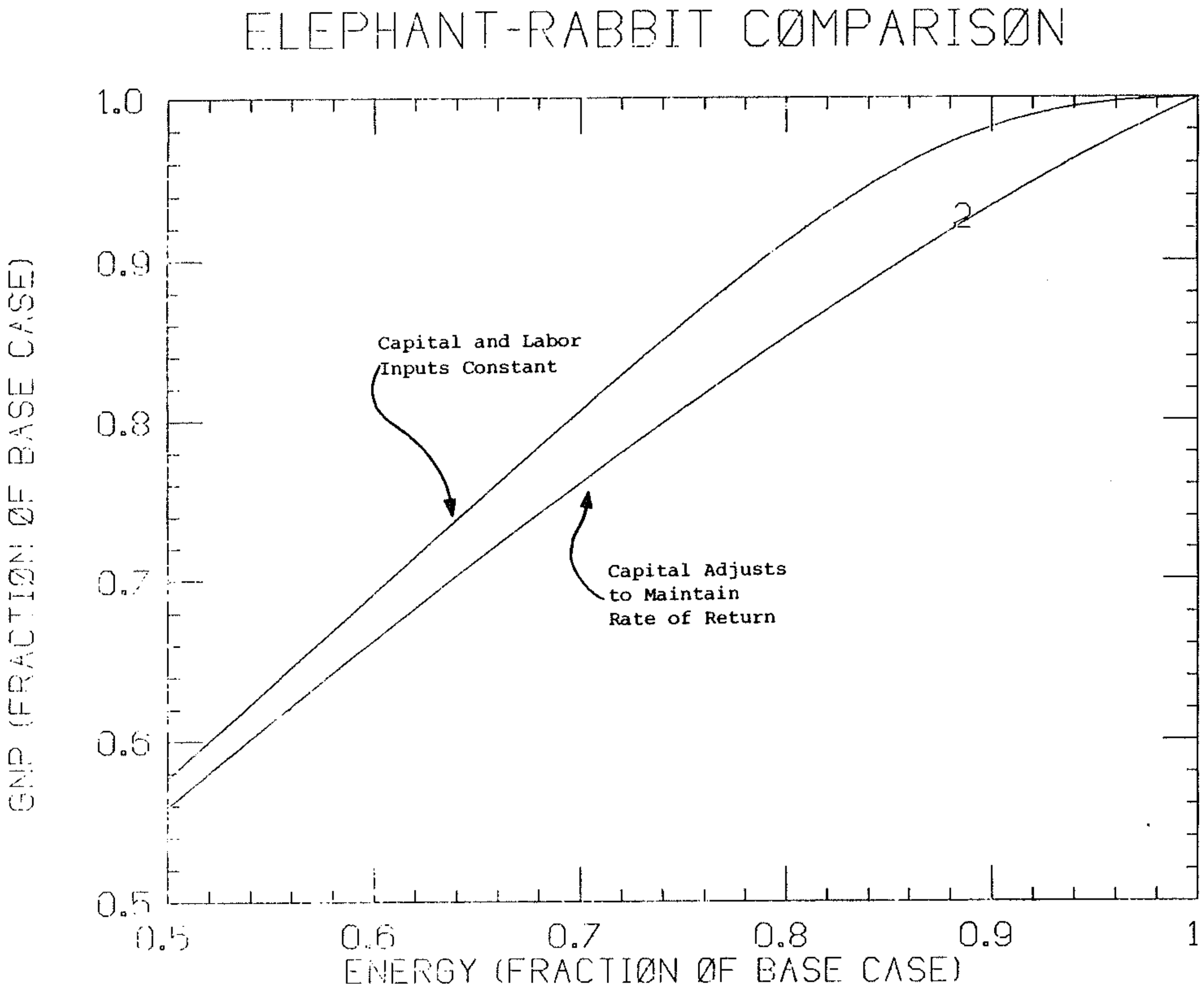


Figure F-43. KENNEDY-NIEMEYER MODEL

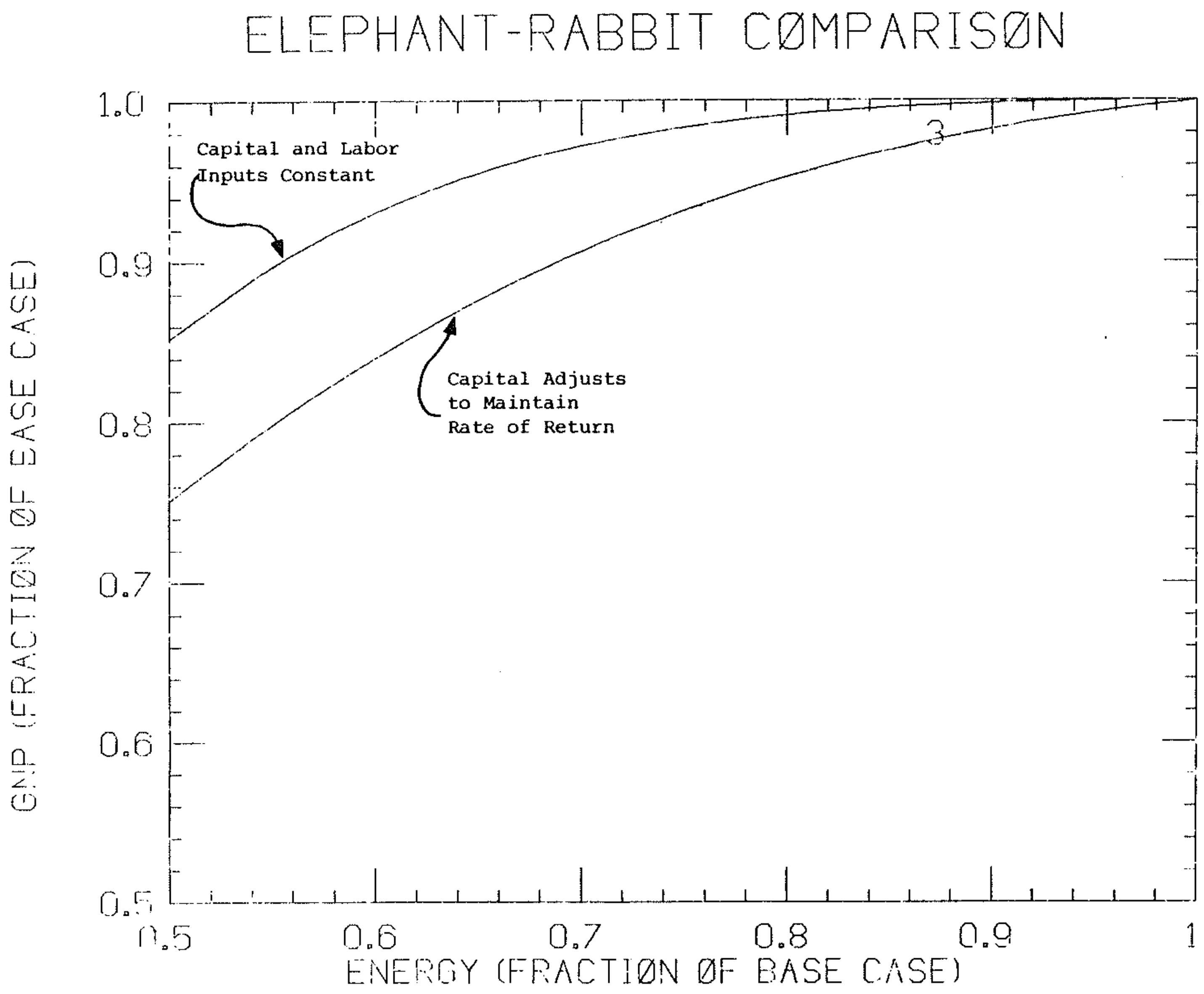


Figure F-44. WHARTON MODEL

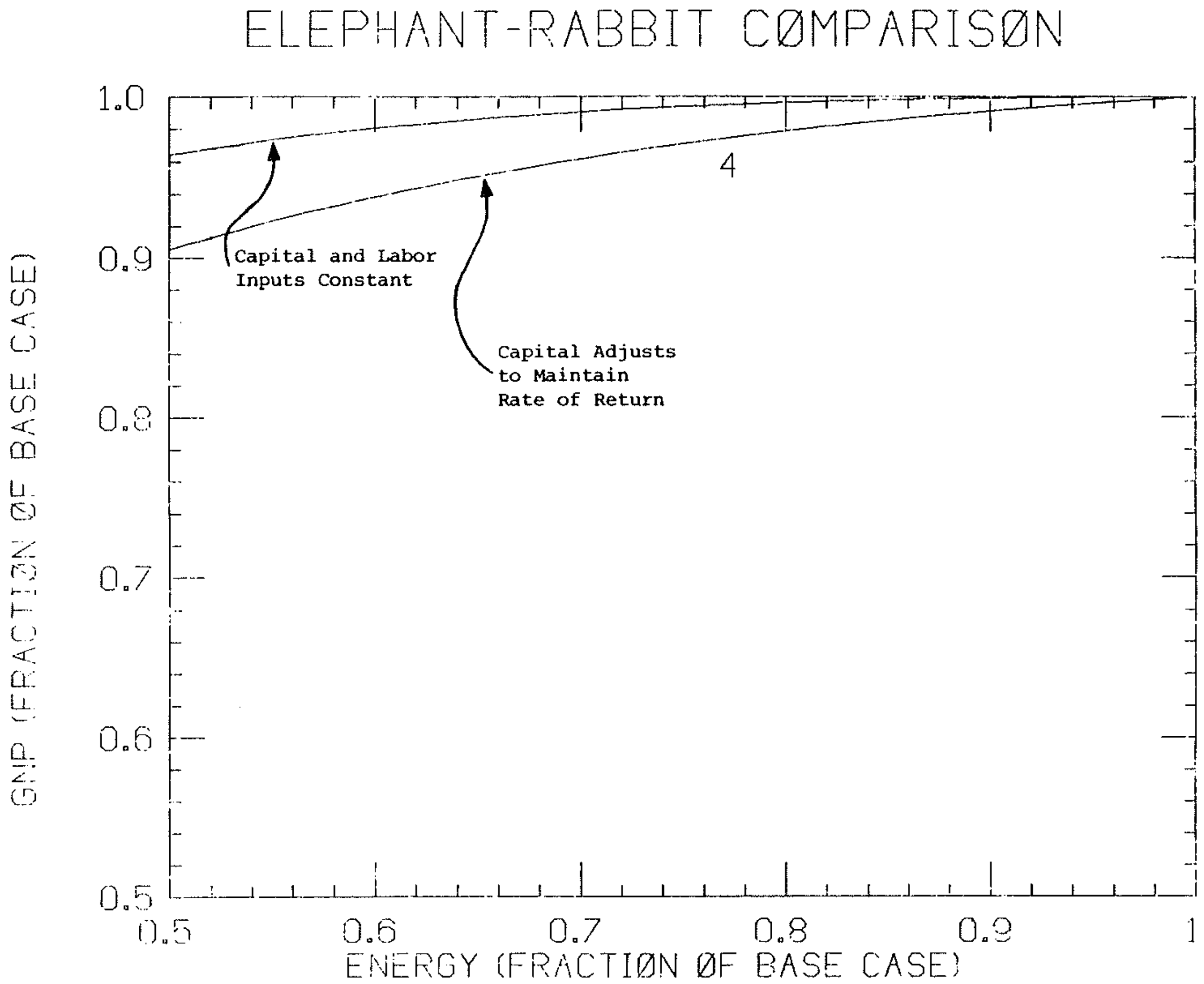


Figure F-45. **HUDSON-JORGENSON MODEL**

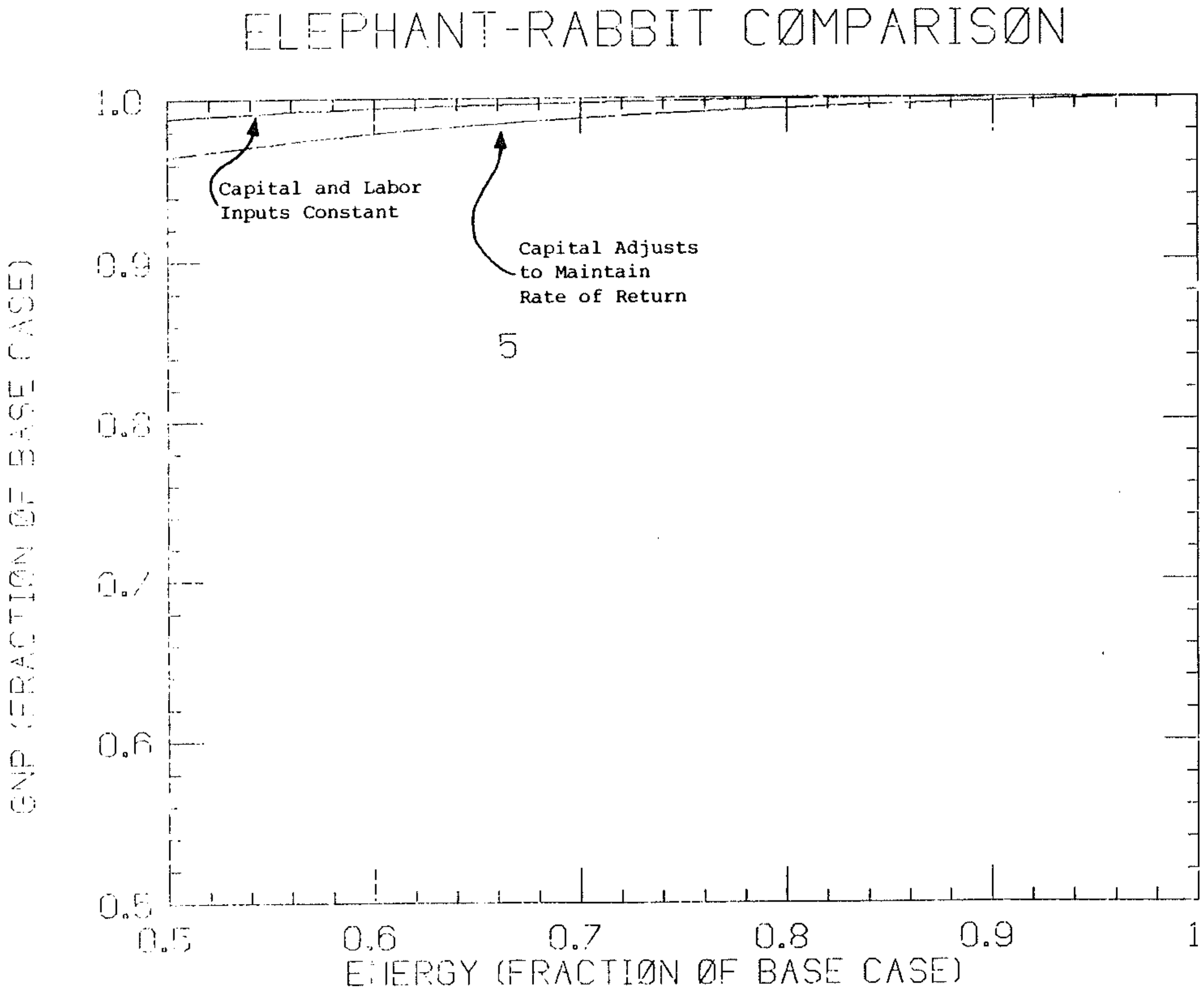


Figure F-46. HNYILICZA MODEL

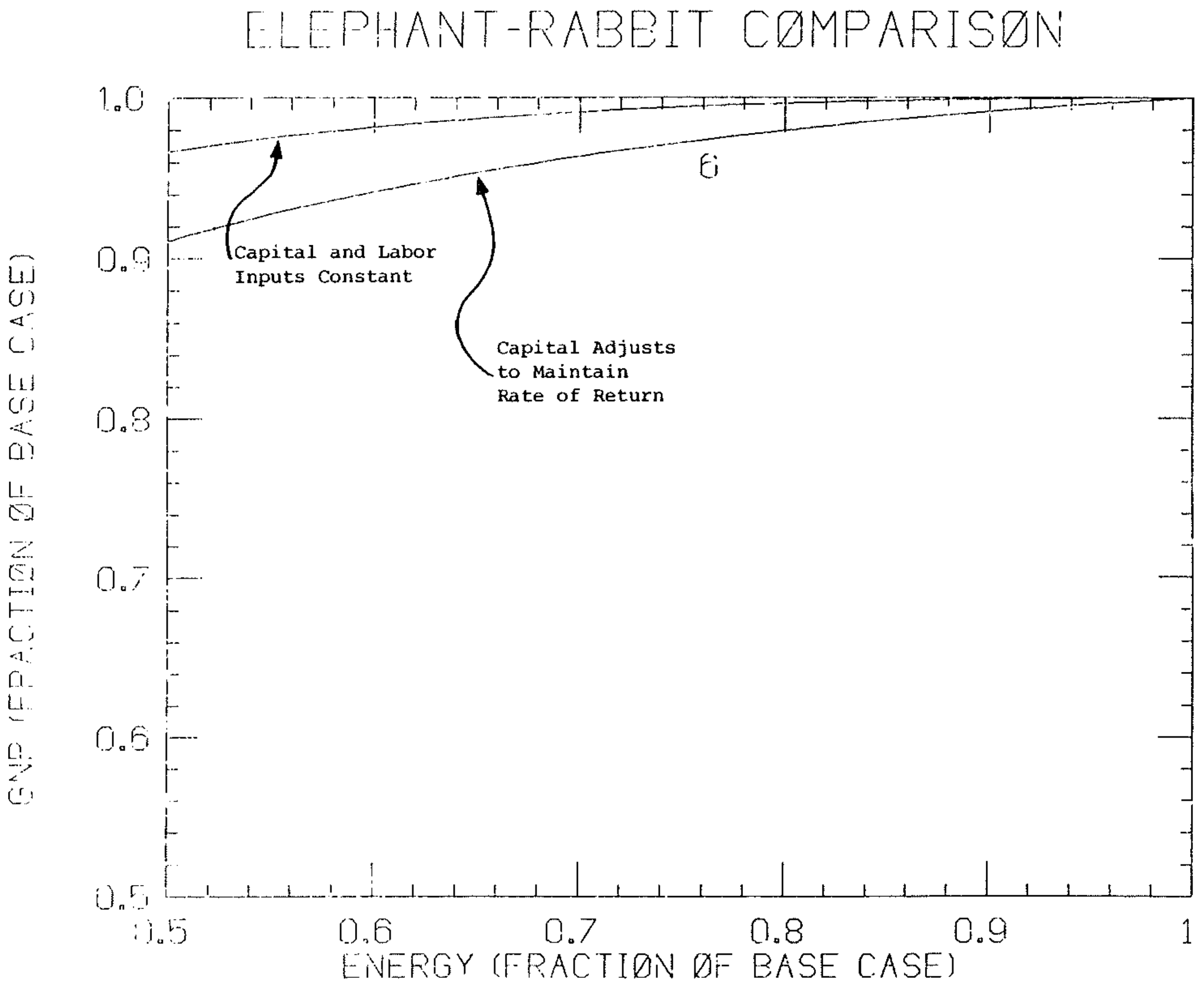


Figure F-47. DRI-BROOKHAVEN MODEL

Section 6

COMPUTER PRINTOUTS

This section contains the full results of scenario runs from various models. Modelers were asked to submit information using EMF designed forms for the essential variables. In some cases, differences in definitions or aggregation levels prevent reporting of comparable detail. For these cases, the modelers provided information on the aggregates or close surrogates. Major discrepancies are cited in the footnotes.

MODEL: PILOT YEAR:	SCENARIO: BASE CASE* 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	1169.900	1355.100	1730.900	2325.600
GROSS PRIVATE DOMESTIC INVESTMENT4	137.200	123.301	235.000	315.000	451.600	325.608
ENERGY	29.060	16.301	51.000	57.800	69.600	8.308
NONENERGY	107.740	107.000	184.000	257.200	382.000	317.500
GOVERNMENT EXPENDITURES	261.000	261.000	405.000	457.400	399.200	805.100
EXPORTS 1	90.600	22.500	0.0	0.0	0.0	0.0
IMPORTS	64.100	22.500	0.0	0.0	0.0	0.0
ENERGY	6.620	0.0	31.600	25.200	16.200	0.0
NONENERGY	57.480	0.0	31.600	20.200	16.200	0.0
GROSS NATIONAL PRODUCT4	1191.700	1177.101	1809.900	2132.300	2781.500	3456.508
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)2						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	13.600	13.500	13.700	13.000
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	10.300	10.000	9.700	9.400
ENERGY NONINTENSIVE MANUFACTURING		0.0	23.200	23.300	22.800	23.100
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	0.0	52.900	53.200	53.900	54.500
TOTAL NONENERGY FINAL DEMAND	1139.000	100.000	100.000	100.000	100.000	100.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	279.700	429.700	513.200	692.900	919.600
ENERGY INTENSIVE MANUFACTURING	382.300	322.300	555.100	645.000	834.000	1033.400
ENERGY NONINTENSIVE MANUFACTURING	534.000	534.000	824.500	979.200	1288.700	1650.720
TRANSPORTATION	81.900	81.900	117.400	138.200	192.500	235.000
SERVICES	935.200	975.300	1432.300	1667.100	2139.200	2939.200
TOTAL NONENERGY GROSS OUTPUT	2213.200	2213.200	3359.000	3942.700	5147.301	6557.898
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.271	*	*	*	*	*
ENERGY PRICES3		3.399	3.348	2.961	2.271	1.937
CAPITAL (INTEREST RATE)	1.089	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	5.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	14.960	32.600	44.400	70.000	90.100
NATURAL GAS	19.200	21.059	22.170	25.220	22.990	8.190
OIL AND NGL	19.573	20.750	31.010	34.590	31.420	12.990
LWR	1.652	2.150	5.760	7.930	20.600	28.550
LMFBR		*	*	*	*	*
OTHER (HTGR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL,SHALE)	3.159	2.840	3.600	3.930	14.570	25.260
ALTERNATIVE ENERGY SYSTEMS		3.690	0.0	0.0	0.0	39.140
OIL AND GAS IMPORTS (QUADS)	13.719	7.980	13.740	8.100	5.520	0.0
TOTAL ENERGY INPUTS (QUADS)	71.079	74.320	108.900	125.470	165.370	204.220
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	27.660	7.920	0.0	0.0	0.0
% COAL	44.500	41.890	57.280	63.640	44.910	45.630
% NUCLEAR	9.000	12.873	21.150	24.030	44.910	45.630
% OTHER	15.900	17.570	13.650	12.330	10.170	8.740
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	29.500	1.090	0.980	1.340	1.000
GAS ($/MCF)	0.780	29.500	4.290	2.670	2.580	2.890
OIL ($/BBL)	8.160	152.130	12.710	11.750	11.610	13.260
ELECTRICITY ($/1000 KWH)	21.220	345.000	51.600	35.920	18.760	33.360
TOTAL ELECTRICITY (TKWH)	1.917	1.620	2.640	3.190	4.470	6.040
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	27.973	1.875	1.531	1.750	1.640

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 NUMBER REPORTED IS NET EXPORTS.

2 NONENERGY FINAL DEMAND COMPOSITION IS REPORTED BY PERCENTAGE BREAKDOWNS RATHER THAN DOLLAR AMOUNTS. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

3 ENERGY PRICE IS BASED EITHER ON SHADOW PRICES OR THE PRICE OF ENERGY IN TERMS OF INVESTMENT DOLLARS NEEDED FOR AES.

4 INVESTMENT FOR AES IS NOT INCLUDED UNDER GROSS PRIVATE DOMESTIC INVESTMENT, ENERGY INVESTMENT, OR GNP.

MODEL: KENNEDY – NIEMEYER SCENARIO: BASE CASE*

YEAR:	1975 ACTUALS	1971.[1]	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	692.000	1032.000	1181.000	1522.000	1925.000
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	161.000	247.000	284.000	370.000	472.000
ENERGY	28.060	30.000	76.000	87.000	113.000	146.000
NONENERGY	109.740	131.000	171.000	197.000	257.000	326.000
GOVERNMENT EXPENDITURES	281.033	238.000	365.000	419.000	545.000	696.000
EXPORTS	90.600	66.000	162.000	187.000	286.000	433.000
IMPORTS	86.100	68.000	110.000	120.000	172.000	229.000
ENERGY	26.620	62.000	91.000	105.000	139.000	184.000
NONENERGY	59.480	6.000	19.000	23.000	33.000	45.000
GROSS NATIONAL PRODUCT	1191.700	1090.000	1666.000	1945.000	2552.000	3297.000
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	131.000	201.000	231.000	301.000	384.000
ENERGY INTENSIVE MANUFACTURING	262.900	354.000	565.000	683.000	922.000	1228.000
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.400	*	*	*	*	*
SERVICES	721.200	573.000	863.000	989.000	1279.000	1624.000
TOTAL NONENERGY FINAL DEMAND	1138.000	1058.000	1648.000	1903.000	2501.000	3236.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	204.000	318.000	367.000	480.000	618.000
ENERGY INTENSIVE MANUFACTURING	382.300	695.000	1132.000	1319.000	1769.000	2340.000
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	941.000	1434.000	1648.000	2146.000	2746.000
TOTAL NONENERGY GROSS OUTPUT	2213.200	1841.000	2883.000	3334.000	4394.000	5704.000
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE[3]		0.670	1.460	1.550	1.790	2.050
CAPITAL (INTEREST RATE)	1.088	0.980	1.040	1.030	1.000	0.970
LABOR	0.977	0.980	1.120	1.220	1.460	1.750
UNEMPLOYMENT RATE (%)	6.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	13.140	19.060	22.190	29.620	38.910
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	46.170	39.550	41.460	44.800	48.730
LWR	1.652	0.320	6.510	8.980	14.260	20.190
LMFBR		*	*	*	*	*
OTHER (THRM, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	2.580	2.720	2.730	2.740	2.760
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[5]	13.719	7.210	36.970	45.630	66.840	92.730
TOTAL ENERGY INPUTS (QUADS)	71.078	69.440	104.910	120.980	158.260	203.320
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	39.000	18.000	13.000	7.000	4.000
% COAL	44.500	43.000	45.000	46.000	46.000	47.000
% NUCLEAR	9.000	2.000	26.000	32.000	39.000	43.000
% OTHER	15.900	16.000	11.000	10.000	7.000	6.000
DOMESTIC PRICES (CONSTANT 1972 $)[6]						
COAL ($/MILLION BTU)	0.830	0.340	0.680	0.640	0.610	0.590
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	8.160	3.720	13.660	15.160	18.590	22.570
ELECTRICITY ($/1000 KWH)	21.220	17.800	25.100	25.700	26.000	25.900
TOTAL ELECTRICITY (TKWH)	1.517	1.614	2.463	2.833	3.493	4.735
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.575	1.962	2.136	2.541	3.002

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

[1] VALUES ARE REPORTED FOR 1971 INSTEAD OF 1975.

[2] UNDER NONENERGY FINAL DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (BOTH ENERGY INTENSIVE AND ENERGY NONINTENSIVE) IS REPORTED AS A SINGLE AGGREGATE VALUE. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

[3] PRICES ARE REPORTED AS INDICES WITH 1975 AS BASE (1.00).

[4] UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE COMBINED AS ONE CATEGORY. ALL NUCLEAR TYPES ARE GROUPED AS ONE CATEGORY; SOLAR ELECTRIC, SOLAR HEATING AND COOLING, AND OTHER ARE REPORTED TOGETHER.

[5] OIL AND GAS IMPORTS INCLUDE AES.

[6] UNDER DOMESTIC PRICES, GAS AND OIL ARE ASSUMED TO HAVE THE SAME PRICES.

MODEL: WHARTON EFA SCENARIO: BASE CASE[1]

YEAR:	1975 ACTUALS	1975.	1980.	1985.	1990.	2000.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	936.400	1080.300	1236.500	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	137.800	215.900	265.400	351.500	0.0
ENERGY	28.060	28.060	34.330	50.660	76.210	0.0
NONENERGY	109.740	109.740	181.570	214.740	275.290	0.0
GOVERNMENT EXPENDITURES	261.030	261.000	302.700	338.400	385.200	0.0
EXPORTS	90.600	90.600	113.200	155.800	192.600	0.0
IMPORTS	68.100	68.100	102.100	133.100	171.000	0.0
ENERGY	8.620	8.620	10.700	13.100	16.200	0.0
NONENERGY	59.480	59.480	91.400	120.000	154.800	0.0
GROSS NATIONAL PRODUCT	1191.700	1191.700	1466.100	1706.700	1994.700	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	120.420	161.920	157.030	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	95.420	103.990	109.080	0.0
ENERGY NONINTENSIVE MANUFACTURING		0.0	297.760	362.690	450.340	0.0
TRANSPORTATION	49.900	0.0	39.340	48.790	62.880	0.0
SERVICES	721.200	0.0	873.830	1008.200	1158.320	0.0
TOTAL NONENERGY FINAL DEMAND	1136.000	0.0	1619.600	1645.610	1923.120	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	90.300	99.600	108.800	123.300	0.0
ENERGY INTENSIVE MANUFACTURING	382.200	84.700	102.800	116.900	135.600	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	165.300	242.100	291.000	361.100	0.0
TRANSPORTATION	81.900	46.500	62.500	76.400	95.600	0.0
SERVICES	935.200	734.200	900.300	1044.500	1203.400	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	1141.000	1406.200	1634.200	1912.400	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX [2]						
IMPLICIT GNP DEFLATOR	1.273	1.273	1.660	2.045	2.492	0.0
ENERGY PRICE		2.010	2.890	3.941	5.305	0.0
CAPITAL (INTEREST RATE)	1.088	1.070	1.600	2.000	2.600	0.0
LABOR	0.977	1.250	1.740	2.350	3.130	0.0
UNEMPLOYMENT RATE (%)	8.500	6.500	5.500	5.900	4.900	0.0
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[3]						
COAL	13.376	13.600	17.200	21.600	24.000	0.0
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL [4]	19.573	53.270	64.650	70.120	76.040	0.0
LWR	1.652	*	*	*	*	*
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS) [4]	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	71.670	86.650	96.520	104.840	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	6.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU)[5]	0.972	0.452	0.650	0.887	1.194	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

1 VALUES ARE REPORTED FOR YEARS 1975,1980,1985, AND 1990, RATHER THAN THE USUAL 1975,1985,1990,2000, AND 2010 BREAKDOWN.

2 PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00).

3 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE GROUPED TOGETHER AS ONE CATEGORY.

4 THE QUANTITY REPORTED FOR OIL AND GAS IS TOTAL SUPPLY. IMPORTS HAVE NOT BEEN DISTINGUISHED SEPARATELY.

5 PRIMARY FOSSIL FUEL PRICE IS BASED ON THE ENERGY PRICE INDEX WHERE 1.00 = $3.22 / MILLION BTU.

MODEL: HUDSON-JORGENSON
YEAR:

SCENARIO:	BASE CASE, 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	0.0	1144.300	1340.300	1808.100	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	0.0	264.200	302.700	411.300	0.0
ENERGY	28.069	*	*	*	*	*
NONENERGY	109.743	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	344.600	408.000	567.400	0.0
EXPORTS	90.630	0.0	19.400	9.000	4.000	0.0
IMPORTS	68.190	*	*	*	*	*
ENERGY	8.820	*	*	*	*	*
NONENERGY	59.400	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1772.600	2060.000	2790.400	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	203.000	226.000	283.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	628.000	720.030	966.400	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	0.0	47.000	53.000	68.000	0.0
SERVICES	721.200	0.0	967.000	1149.000	1604.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.030	0.0	1845.000	2150.000	2924.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	326.000	362.000	451.000	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	0.0	1305.000	1514.000	2031.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	634.000	*	*	*	*	*
TRANSPORTATION	61.900	0.0	129.000	149.000	197.800	0.0
SERVICES	935.200	0.0	1556.000	1826.000	2489.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3316.000	3851.000	5168.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX[3]						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.222	2.839	4.920	0.0
CAPITAL (INTEREST RATE)	1.088	0.0	2.272	2.645	3.832	0.0
LABOR	0.977	0.0	2.390	3.039	4.797	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[5]						
COAL	13.376	0.0	20.600	25.800	37.800	0.0
NATURAL GAS	19.600	0.0	22.400	22.400	19.300	0.0
OIL AND NGL	19.973	0.0	29.400	29.200	22.800	0.0
LWR	1.652	0.0	7.960	14.600	28.800	0.0
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		0.0	3.800	4.100	4.300	0.0
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	0.0	0.200	0.600	3.400	0.0
ALTERNATIVE ENERGY SYSTEMS		0.0	0.600	1.000	2.800	0.0
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	12.200	12.490	21.800	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	97.372	110.140	140.219	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	18.000	14.000	6.000	0.0
% COAL	44.500	0.0	46.000	40.000	31.000	0.0
% NUCLEAR	9.000	0.0	24.000	35.000	51.000	0.0
% OTHER	15.900	0.0	12.000	11.000	13.000	0.0
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.830	0.0	0.479	0.503	0.658	0.0
GAS ($/MCF)	0.780	0.0	1.564	1.603	1.776	0.0
OIL ($/BBL)	8.160	0.0	10.208	10.711	13.077	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	29.391	27.426	29.627	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	3.313	4.180	5.479	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	1.318	1.372	1.698	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

[1] VALUES ARE REPORTED FOR YEARS 1985,1990, AND 2000 ONLY.

[2] UNDER NONENERGY DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (ENERGY INTENSIVE AND NONINTENSIVE) IS AGGREGATED AS ONE CATEGORY.

[3] PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00); THE ENERGY PRICE INDEX IS FOR DELIVERED ENERGY.

[4] FOR THE HIGH GROWTH CASE, THE CONSTRAINED HIGH GROWTH CASE, AND THE CONSTRAINED BASE CASE, THE VALUE REPORTED FOR LWR UNDER DOMESTIC PRODUCTION INCLUDES HYDRO, OTHER ELECTRIC SOURCES, AND SHALE.

[5] FOR THE BASE CASE AND DECLINING OIL PRICE CASE, THE FOLLOWING CHANGES HAVE BEEN MADE IN REPORTING UNDER DOMESTIC ENERGY PRODUCTION:
   A) THE VALUE REPORTED FOR SOLAR HEATING AND COOLING IS ACTUALLY HYDROPOWER PRODUCTION.
   B) THE VALUE REPORTED FOR OTHER IS OTHER ELECTRICITY SOURCES.
   C) THE VALUE REPORTED FOR AES IS ACTUALLY SHALE PRODUCTION.

MODEL: HNYLICZA YEAR:	SCENARIO: BASE CASE! 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	*	*	*	*	*
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	*	*	*	*	*
ENERGY	26.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	*	*	*	*	*
EXPORTS	90.600	*	*	*	*	*
IMPORTS	66.100	*	*	*	*	*
ENERGY	6.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	1393.733	1736.300	1936.119	2385.710	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	262.900	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	*	*	*	*	*
TOTAL NONENERGY FINAL DEMAND	1136.000	*	*	*	*	*
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	382.300	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	*	*	*	*	*
TOTAL NONENERGY GROSS OUTPUT	2213.200	*	*	*	*	*
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	1.011	1.394	1.632	2.173	0.0
ENERGY PRICE 1		0.424	0.378	0.348	0.288	0.0
CAPITAL (INTEREST RATE)	1.088	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	*	*	*	*	*
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	*	*	*	*	*
LWR	1.652	*	*	*	*	*
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	75.900	95.500	105.300	124.400	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) 1	0.672	0.424	0.378	0.348	0.288	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
1 ENERGY PRICE IS IN 1972 $/MILLION BTU.

MODEL: DRI-BESOM SCENARIO: BASE CASE*

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $) 1						
CONSUMPTION	770.300	0.0	1144.300	1340.300	1808.100	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	264.200	302.700	411.300	0.0
ENERGY	26.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	344.600	408.000	567.000	0.0
EXPORTS	90.000	0.0	19.400	9.000	4.000	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1772.600	2060.000	2790.400	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	203.000	228.000	283.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	628.000	720.000	966.000	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	0.0	47.000	53.000	68.000	0.0
SERVICES	721.200	0.0	967.000	1149.000	1604.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1845.000	2150.000	2924.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	326.000	362.000	451.000	0.0
ENERGY INTENSIVE MANUFACTURING	362.300	0.0	1305.000	1514.000	2031.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	0.0	129.000	149.000	197.000	0.0
SERVICES	935.200	0.0	1556.000	1826.000	2489.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3316.000	3851.000	6168.800	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.222	2.839	4.920	0.0
CAPITAL (INTEREST RATE)	1.068	0.0	2.272	2.645	3.532	0.0
LABOR	0.977	0.0	2.390	3.039	4.797	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	0.0	20.180	25.600	32.640	0.0
NATURAL GAS	19.200	0.0	23.030	21.400	22.410	0.0
OIL AND NGL	19.973	0.0	29.400	30.280	25.300	0.0
LWR	1.652	0.0	7.960	12.000	24.000	0.0
LMFBR		0.0	0.0	0.0	1.550	0.0
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		0.0	0.180	0.450	3.200	0.0
SOLAR HEATING AND COOLING		0.0	0.160	0.460	1.160	0.0
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	0.0	3.600	4.100	4.300	0.0
ALTERNATIVE ENERGY SYSTEMS		0.0	0.300	1.000	3.000	0.0
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	12.340	14.850	22.470	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	97.370	110.140	140.220	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	17.000	14.000	6.800	0.0
% COAL	44.500	0.0	46.000	45.000	33.000	0.0
% NUCLEAR	9.000	0.0	24.000	30.000	46.000	0.0
% OTHER	15.900	0.0	13.000	11.000	15.000	0.0
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	0.479	0.503	0.558	0.0
GAS ($/MCF)	0.780	0.0	1.564	1.603	1.776	0.0
OIL ($/BBL)	6.160	0.0	10.216	10.711	13.877	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	27.969	27.552	26.578	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	2.921	3.601	5.245	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	1.328	1.381	1.609	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 THE NONENERGY SECTOR NUMBERS REPORTED ARE THE SAME AS IN THE HUDSON-JORGENSON RUNS. THE BROOKHAVEN MODEL HAS BEEN RUN WITH THESE VALUES TO OBTAIN GREATER ENERGY SECTOR DETAIL.

2 SEE THE FOOTNOTES FOR THE HUDSON-JORGENSON MODEL.

MODEL: KENNEDY - NIEMEYER   SCENARIO: DECLINING OIL IMPORT PRICE*

YEAR:	1975 ACTUALS	1971.[1]	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	692.000	1046.000	1212.000	1583.000	2029.000
GROSS PRIVATE DOMESTIC INVESTMENT	137.000	161.000	248.000	288.000	378.000	488.000
ENERGY	28.060	30.000	67.000	72.000	91.000	115.000
NONENERGY	109.740	131.000	181.000	216.000	287.000	373.000
GOVERNMENT EXPENDITURES	261.000	236.000	367.000	425.000	559.000	721.000
EXPORTS	90.600	66.000	143.000	172.000	262.000	389.000
IMPORTS	68.100	68.000	113.000	134.000	181.000	243.000
ENERGY	8.620	62.000	92.000	107.000	142.000	189.000
NONENERGY	59.460	6.000	21.000	27.000	39.000	54.000
GROSS NATIONAL PRODUCT	1191.700	1090.000	1692.000	1963.000	2601.000	3384.000
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	131.000	202.000	234.000	308.000	379.000
ENERGY INTENSIVE MANUFACTURING	262.900	354.000	561.000	679.000	923.000	1230.000
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.590	*	*	*	*	*
SERVICES	721.200	573.000	872.000	1010.000	1323.000	1700.000
TOTAL NONENERGY FINAL DEMAND	1138.000	1058.000	1656.000	1924.000	2554.000	3327.090
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	204.000	319.000	370.000	490.000	636.000
ENERGY INTENSIVE MANUFACTURING	382.390	695.000	1129.000	1317.000	1778.000	2357.000
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	941.000	1445.000	1675.000	2204.000	2849.000
TOTAL NONENERGY GROSS OUTPUT	2213.200	1841.000	2692.000	3362.000	4472.000	5841.000
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE [3]		0.670	1.210	1.190	1.360	2.280
CAPITAL (INTEREST RATE)	1.088	0.960	1.050	1.040	0.990	0.950
LABOR	0.977	0.980	1.140	1.260	1.560	1.900
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	13.140	19.110	22.350	30.890	39.730
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	46.170	34.500	31.320	28.280	27.900
LWR	1.652	0.320	6.600	9.130	14.750	21.050
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	2.580	2.730	2.730	2.750	2.760
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[5]	13.719	7.210	41.960	55.870	84.340	116.160
TOTAL ENERGY INPUTS (QUADS)	71.078	69.440	104.900	121.470	160.200	207.600
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	39.000	17.000	13.000	7.800	4.000
% COAL	44.500	43.000	45.000	46.000	47.800	47.000
% NUCLEAR	9.000	2.000	27.000	32.000	39.000	43.000
% OTHER	15.900	16.000	11.000	9.000	7.800	6.000
DOMESTIC PRICES (CONSTANT 1972 $)[6]						
COAL ($/MILLION BTU)	0.630	0.340	0.690	0.650	0.630	0.620
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	3.720	10.210	9.860	12.270	14.970
ELECTRICITY ($/1000 KWH)	21.220	17.800	25.100	25.700	25.800	25.600
TOTAL ELECTRICITY (TKWH)	1.917	1.614	2.482	2.877	3.792	4.907
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.575	1.488	1.430	1.696	1.985

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)
1 VALUES ARE REPORTED FOR 1971 INSTEAD OF 1975.
2 UNDER NONENERGY FINAL DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (BOTH ENERGY INTENSIVE AND ENERGY NONINTENSIVE) IS REPORTED AS A SINGLE AGGREGATE VALUE. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.
3 PRICES ARE REPORTED AS INDICES WITH 1975 AS BASE (1.00).
4 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE COMBINED AS ONE CATEGORY. ALL NUCLEAR TYPES ARE GROUPED AS ONE CATEGORY; SOLAR ELECTRIC, SOLAR HEATING AND COOLING, AND OTHER ARE REPORTED TOGETHER.
5 OIL AND GAS IMPORTS INCLUDE AES.
6 UNDER DOMESTIC PRICES, GAS AND OIL ARE ASSUMED TO HAVE THE SAME PRICES.

MODEL: WHARTON EFA SCENARIO: DECLINING OIL IMPORT PRICE[1]

YEAR:	1975 ACTUALS	1975.	1980.	1985.	1990.	2000.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	946.300	1108.500	1272.800	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	137.800	219.500	281.200	375.100	0.0
ENERGY	28.000	28.000	34.460	53.040	88.040	0.0
NONENERGY	109.740	109.740	185.040	228.160	287.060	0.0
GOVERNMENT EXPENDITURES	261.000	261.000	302.700	338.400	365.203	0.0
EXPORTS	90.600	90.600	114.000	158.500	196.400	0.0
IMPORTS	68.100	68.100	103.300	138.000	178.400	0.0
ENERGY	8.620	8.620	10.900	13.680	16.930	0.0
NONENERGY	59.480	59.480	92.400	124.320	161.570	0.0
GROSS NATIONAL PRODUCT	1191.700	1191.700	1479.200	1748.600	2050.900	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	121.700	138.830	169.850	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	95.360	105.840	110.740	0.0
ENERGY NONINTENSIVE MANUFACTURING		0.0	301.570	374.020	462.890	0.0
TRANSPORTATION	49.900	0.0	39.620	50.010	64.580	0.0
SERVICES	721.200	0.0	879.210	1026.640	1185.920	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1430.270	1686.760	1979.090	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	90.300	100.600	113.600	131.600	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	64.700	103.800	120.000	139.300	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	165.300	244.500	300.500	372.200	0.0
TRANSPORTATION	81.900	46.500	63.000	78.100	98.100	0.0
SERVICES	935.200	734.200	906.000	1065.900	1232.300	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	1141.000	1416.700	1674.700	1966.900	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX[2]						
IMPLICIT GNP DEFLATOR	1.273	1.273	1.651	2.006	2.483	0.0
ENERGY PRICE		2.010	2.731	3.129	4.016	0.0
CAPITAL (INTEREST RATE)	1.086	1.070	1.650	1.940	2.500	0.0
LABOR	0.977	1.250	1.750	2.330	3.140	0.0
UNEMPLOYMENT RATE (%)	6.500	8.500	5.100	4.500	2.800	0.0
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[3]						
COAL	13.376	13.600	17.600	23.200	26.800	0.0
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL[4]	19.973	53.270	65.563	71.482	78.312	0.0
CAR	1.652	*	*	*	*	*
EMPGR		*	*	*	*	*
OTHER (MWH, BTUR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[4]	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	71.670	87.963	99.482	109.912	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	6.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU)[5]	0.972	0.452	0.614	0.704	0.903	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

[1] VALUES ARE REPORTED FOR YEARS 1975,1980,1985, AND 1990, RATHER THAN THE USUAL 1975,1985,1990,2000, AND 2010 BREAKDOWN.

[2] PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00).

[3] UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE GROUPED TOGETHER AS ONE CATEGORY.

[4] THE QUANTITY REPORTED FOR OIL AND GAS IS TOTAL SUPPLY. IMPORTS HAVE NOT BEEN DISTINGUISHED SEPARATELY.

[5] PRIMARY FOSSIL FUEL PRICE IS BASED ON THE ENERGY PRICE INDEX WHERE 1.00 = $0.22 / MILLION BTU.

MODEL: HUDSON-JORGENSON SCENARIO: DECLINING OIL IMPORT PRICE¹

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	0.0	1150.800	1350.300	1821.500	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	266.000	305.500	417.100	0.0
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.090	0.0	344.600	408.000	567.000	0.0
EXPORTS	90.600	0.0	19.000	7.800	1.900	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1760.400	2071.600	2807.900	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)2						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.030	0.0	205.300	232.000	287.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	632.000	725.000	977.000	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	0.0	48.000	55.000	70.000	0.0
SERVICES	721.200	0.0	970.000	1153.000	1606.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.030	0.0	1855.000	2165.000	2940.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $) 2						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	329.000	367.000	457.000	0.0
ENERGY INTENSIVE MANUFACTURING	362.300	0.0	1310.000	1521.000	2040.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	61.900	0.0	130.000	151.000	200.000	0.0
SERVICES	935.200	0.0	1560.000	1828.000	2499.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3329.000	3867.000	6196.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX3						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.124	2.715	4.649	0.0
CAPITAL (INTEREST RATE)	1.046	0.0	2.272	2.645	3.932	0.0
LABOR	0.977	0.0	2.394	3.056	4.836	0.0
UNEMPLOYMENT RATE (%)	6.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)5						
COAL	13.376	0.0	20.400	25.500	37.500	0.0
NATURAL GAS	19.230	0.0	21.700	21.700	18.700	0.0
OIL AND NGL	19.573	0.0	29.400	29.200	22.000	0.0
LWR	1.652	0.0	7.800	14.400	28.300	0.0
LMFBR		*	*	*	*	*
OTHER (MHR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		0.0	3.800	4.100	4.300	0.0
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	0.0	0.200	0.600	3.400	0.0
ALTERNATIVE ENERGY SYSTEMS		0.0	0.640	1.000	2.800	0.0
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	15.000	15.800	26.300	0.0
TOTAL ENERGY INPUTS (QUADS)	71.076	0.0	98.900	112.300	143.300	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	19.000	15.000	7.000	0.0
% COAL	44.500	0.0	46.000	40.000	30.000	0.0
% NUCLEAR	9.000	0.0	23.000	34.000	50.000	0.0
% OTHER	15.900	0.0	12.000	11.000	13.000	0.0
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	0.479	0.503	0.558	0.0
GAS ($/MCF)	0.760	0.0	1.564	1.603	1.776	0.0
OIL ($/BBL)	8.160	0.0	6.692	9.132	11.159	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	29.234	27.348	29.470	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	3.357	4.227	5.691	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	1.213	1.263	1.467	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 VALUES ARE REPORTED FOR YEARS 1985,1990, AND 2000 ONLY.

2 UNDER NONENERGY DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (ENERGY INTENSIVE AND NONINTENSIVE) IS AGGREGATED AS ONE CATEGORY.

3 PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00); THE ENERGY PRICE INDEX IS FOR DELIVERED ENERGY.

4 FOR THE HIGH GROWTH CASE, THE CONSTRAINED HIGH GROWTH CASE, AND THE CONSTRAINED BASE CASE, THE VALUE REPORTED FOR LWR UNDER DOMESTIC PRODUCTION INCLUDES HYDRO, OTHER ELECTRIC SOURCES, AND SHALE.

5 FOR THE BASE CASE AND DECLINING OIL PRICE CASE, THE FOLLOWING CHANGES HAVE BEEN MADE IN REPORTING UNDER DOMESTIC ENERGY PRODUCTION:

A) THE VALUE REPORTED FOR SOLAR HEATING AND COOLING IS ACTUALLY HYDROPOWER PRODUCTION.

B) THE VALUE REPORTED FOR OTHER IS OTHER ELECTRICITY SOURCES.

C) THE VALUE REPORTED FOR A&S IS ACTUALLY SHALE PRODUCTION.

MODEL: HNYILICZA SCENARIO: DECLINING OIL IMPORT PRICE'

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	816.000	1054.600	1190.500	1492.600	1859.400
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	566.890	659.400	713.900	872.000	1152.700
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	*	*	*	*	*
EXPORTS	90.600	*	*	*	*	*
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	2410.536	3015.743	3366.788	4230.699	5452.922
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	262.900	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	*	*	*	*	*
TOTAL NONENERGY FINAL DEMAND	1136.000	*	*	*	*	*
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	382.300	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	*	*	*	*	*
TOTAL NONENERGY GROSS OUTPUT	2213.200	*	*	*	*	*
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	1.011	1.400	1.645	2.239	3.019
ENERGY PRICE 1		*	*	*	*	*
CAPITAL (INTEREST RATE)	1.086	1.820	2.790	3.410	4.580	6.930
LABOR	0.977	1.890	3.040	3.850	5.900	8.850
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	*	*	*	*	*
NATURAL GAS	19.209	*	*	*	*	*
OIL AND NGL	19.973	*	*	*	*	*
LWR	1.652	*	*	*	*	*
BREEDER		*	*	*	*	*
OTHER (MHD, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	76.120	99.770	112.250	133.310	162.920
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) 1	0.972	*	*	*	*	*

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
1 ENERGY PRICE IS IN 1972 $/MILLION BTU.

MODEL: DRI-BESOM SCENARIO: DECLINING OIL IMPORT PRICE*

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)[1]						
CONSUMPTION	770.300	0.0	1150.800	1350.300	1821.900	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	266.000	305.500	417.100	0.0
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	344.600	408.000	567.000	0.0
EXPORTS	90.600	0.0	19.000	7.800	1.900	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1760.400	2071.600	2807.900	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE, NONFUEL MINING, CONSTRUCTION	104.030	0.0	205.000	232.000	287.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	632.000	725.000	977.000	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	0.0	48.000	65.000	70.000	0.0
SERVICES	721.200	0.0	970.000	1153.000	1606.300	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1855.000	2165.000	2940.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE, NONFUEL MINING, CONSTRUCTION	279.700	0.0	329.000	367.000	457.000	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	0.0	1310.000	1521.000	2040.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	0.0	130.000	151.000	200.000	0.0
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	0.0	1560.000	1828.000	2499.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3329.000	3867.000	6196.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.124	2.715	4.649	0.0
CAPITAL (INTEREST RATE)	1.088	0.0	2.272	2.645	3.532	0.0
LABOR	0.977	0.0	2.394	3.056	4.836	0.0
UNEMPLOYMENT RATE (%)	6.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	0.0	20.540	25.810	33.120	0.0
NATURAL GAS	19.200	0.0	13.870	12.990	22.830	0.0
OIL AND NGL	19.973	0.0	28.520	29.370	24.540	0.0
LWR	1.652	0.0	7.600	11.800	23.800	0.0
BREEDER		0.0	0.0	0.0	1.250	0.0
OTHER (MARI. HIGR)		*	*	*	*	*
SOLAR ELECTRIC		0.0	0.180	0.450	3.200	0.0
SOLAR HEATING AND COOLING		0.0	0.160	0.460	1.160	0.0
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	0.0	3.800	4.100	4.300	0.0
ALTERNATIVE ENERGY SYSTEMS		0.0	0.300	1.000	0.0	0.0
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	23.730	26.320	29.100	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	98.900	112.300	143.300	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	19.000	14.000	7.000	0.0
% COAL	44.500	0.0	46.000	45.000	43.800	0.0
% NUCLEAR	9.000	0.0	23.000	30.000	45.000	0.0
% OTHER	15.900	0.0	12.000	11.000	5.000	0.0
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	0.479	0.503	0.558	0.0
GAS ($/MCF)	0.780	0.0	1.564	1.603	1.776	0.0
OIL ($/BBL)	8.160	0.0	8.692	9.132	11.159	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	27.788	27.450	26.878	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	2.947	3.614	5.252	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	1.170	1.219	1.421	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 THE NONENERGY SECTOR NUMBERS REPORTED ARE THE SAME AS IN THE HUDSON-JORGENSON RUNS. THE BROOKHAVEN MODEL HAS BEEN RUN WITH THESE VALUES TO OBTAIN GREATER ENERGY SECTOR DETAIL.

2 SEE THE FOOTNOTES FOR THE HUDSON-JORGENSON MODEL.

MODEL: PILOT SCENARIO: HIGH GROWTH CASE*

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	1180.400	1557.900	2110.500	3226.600
GROSS PRIVATE DOMESTIC INVESTMENT[4]	137.800	122.929	439.333	364.989	664.765	489.347
ENERGY	28.060	15.829	62.233	75.186	45.065	17.847
NONENERGY	109.740	107.000	377.000	294.800	618.700	471.500
GOVERNMENT EXPENDITURES	261.000	261.000	409.300	539.200	731.200	1110.900
EXPORTS[1]	96.630	22.300	0.0	0.0	0.0	0.0
IMPORTS	68.100	22.500	0.0	0.0	0.0	0.0
ENERGY	8.620	0.0	39.800	41.400	36.900	0.0
NONENERGY	59.490	0.0	39.800	41.400	36.900	0.0
GROSS NATIONAL PRODUCT[4]	1191.700	1176.629	2029.633	2467.089	3506.465	4512.648
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	13.500	13.800	13.900	13.000
ENERGY INTENSIVE MANUFACTURING	362.900	0.0	9.900	9.700	9.200	9.500
ENERGY NONINTENSIVE MANUFACTURING		0.0	23.000	23.800	23.900	23.100
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	0.0	53.600	52.700	53.100	54.400
TOTAL NONENERGY FINAL DEMAND	1138.000	100.000	100.000	100.000	100.000	100.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	276.700	530.200	603.400	912.600	1236.000
ENERGY INTENSIVE MANUFACTURING	362.300	382.300	624.200	746.400	1057.800	1425.500
ENERGY NONINTENSIVE MANUFACTURING	534.000	534.000	1051.900	1177.600	1785.400	2477.100
TRANSPORTATION	81.900	81.900	139.100	173.900	244.200	334.700
SERVICES	935.200	938.300	1522.100	1937.700	2698.100	3993.800
TOTAL NONENERGY GROSS OUTPUT	2211.200	2213.200	3867.500	4639.000	5702.102	9437.102
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.279	*	*	*	*	*
ENERGY PRICES[3]		3.451	4.251	3.969	3.151	3.929
CAPITAL (INTEREST RATE)	1.083	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	9.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.375	14.910	32.600	44.400	70.000	90.100
NATURAL GAS	19.209	21.050	22.170	25.220	22.950	8.180
OIL AND NGL	13.573	20.750	31.010	34.890	31.490	12.990
LWR	1.652	2.150	5.780	9.340	26.090	39.980
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.155	2.840	3.600	3.930	14.570	25.260
ALTERNATIVE ENERGY SYSTEMS		3.810	4.140	4.940	18.740	96.140
OIL AND GAS IMPORTS (QUADS)	13.719	7.930	17.490	16.280	11.440	0.0
TOTAL ENERGY INPUTS (QUADS)	71.074	73.440	116.780	139.000	195.320	272.650
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	24.910	9.000	0.0	0.0	0.0
% COAL	44.500	44.680	54.360	67.180	45.860	46.800
% NUCLEAR	9.000	12.860	19.940	22.050	45.860	46.800
% OTHER	15.900	17.550	12.900	10.770	8.280	6.400
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	47.130	1.340	1.640	1.890	1.530
GAS ($/MCF)	0.750	47.130	5.470	3.750	3.570	2.900
OIL ($/BBL)	8.160	243.050	15.530	17.200	16.730	13.340
ELECTRICITY ($/1000 KWH)	21.220	555.070	71.550	41.670	21.620	36.010
TOTAL ELECTRICITY (TKWH)	1.917	1.620	2.510	3.650	5.530	8.250
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	44.690	2.212	2.284	2.405	1.947

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 NUMBER REPORTED IS NET EXPORTS.

2 NONENERGY FINAL DEMAND COMPOSITION IS REPORTED BY PERCENTAGE BREAKDOWNS RATHER THAN DOLLAR AMOUNTS. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

3 ENERGY PRICE IS BASED EITHER ON SHADOW PRICES OR THE PRICE OF ENERGY IN TERMS OF INVESTMENT DOLLARS NEEDED FOR AES.

4 INVESTMENT FOR AES IS NOT INCLUDED UNDER GROSS PRIVATE DOMESTIC INVESTMENT, ENERGY INVESTMENT, OR GNP.

MODEL: KENNEDY - NIEMEYER SCENARIO: HIGH GROWTH CASE*

YEAR:	1975 ACTUALS	1971.[1]	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.200	692.000	1108.000	1299.000	1836.000	2535.000
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	161.000	265.000	312.000	446.000	623.000
ENERGY	28.060	30.000	61.000	94.000	134.000	188.000
NONENERGY	109.740	131.000	184.000	218.000	312.000	435.000
GOVERNMENT EXPENDITURES	201.000	238.000	352.000	461.000	658.000	919.000
EXPORTS	90.600	65.000	164.000	208.000	351.000	585.000
IMPORTS	66.100	68.000	117.000	140.000	201.000	284.000
ENERGY	8.620	62.000	97.000	115.000	160.000	222.000
NONENERGY	59.480	6.000	20.000	25.000	41.000	62.000
GROSS NATIONAL PRODUCT	1191.700	1090.000	1811.000	2140.000	3090.000	4378.000
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	131.000	216.000	255.000	364.000	507.000
ENERGY INTENSIVE MANUFACTURING	262.500	354.000	629.000	753.000	1126.000	1658.000
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	45.900	*	*	*	*	*
SERVICES	721.200	573.000	926.000	1088.000	1642.000	2137.000
TOTAL NONENERGY FINAL DEMAND	1138.000	1058.000	1771.000	2095.000	3031.000	4302.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	204.000	341.000	403.000	581.000	819.000
ENERGY INTENSIVE MANUFACTURING	382.300	695.000	1218.000	1454.000	2157.000	3147.000
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.930	*	*	*	*	*
SERVICES	935.200	941.000	1543.000	1813.000	2552.000	3628.000
TOTAL NONENERGY GROSS OUTPUT	2213.200	1841.000	3099.000	3670.000	5330.000	7595.000
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE[3]		0.670	1.460	1.560	1.820	2.110
CAPITAL (INTEREST RATE)	1.086	0.960	1.040	1.030	1.060	1.030
LABOR	0.977	0.980	1.190	1.330	1.610	1.990
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	13.140	20.540	24.500	35.960	51.710
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	46.170	41.650	44.420	48.680	53.380
LWR	1.652	0.320	7.370	10.350	18.870	27.810
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	2.580	2.750	2.750	2.780	2.610
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[5]	13.719	7.210	40.340	51.140	85.780	133.180
TOTAL ENERGY INPUTS (QUADS)	71.078	69.440	112.650	133.170	191.270	268.900
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	39.000	17.000	12.000	6.000	3.000
% COAL	44.500	43.000	45.000	46.000	47.000	48.000
% NUCLEAR	9.000	2.000	28.000	33.000	40.000	44.000
% OTHER	15.900	16.000	10.000	9.000	6.000	4.000
DOMESTIC PRICES (CONSTANT 1972 $)[6]						
COAL ($/MILLION BTU)	0.830	0.340	0.690	0.640	0.610	0.590
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	8.160	3.720	13.690	15.210	18.830	23.120
ELECTRICITY ($/1000 KWH)	21.220	17.600	25.400	25.900	27.500	27.500
TOTAL ELECTRICITY (TKWH)	1.917	1.614	2.645	3.117	4.467	6.272
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.576	1.959	2.127	2.646	3.032

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

[1] VALUES ARE REPORTED FOR 1971 INSTEAD OF 1975.

[2] UNDER NONENERGY FINAL DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (BOTH ENERGY INTENSIVE AND ENERGY NONINTENSIVE) IS REPORTED AS A SINGLE AGGREGATE VALUE. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

[3] PRICES ARE REPORTED AS INDICES WITH 1975 AS BASE (1.00).

[4] UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE COMBINED AS ONE CATEGORY. ALL NUCLEAR TYPES ARE GROUPED AS ONE CATEGORY; SOLAR ELECTRIC, SOLAR HEATING AND COOLING, AND OTHER ARE REPORTED TOGETHER.

[5] OIL AND GAS IMPORTS INCLUDE AES.

[6] UNDER DOMESTIC PRICES, GAS AND OIL ARE ASSUMED TO HAVE THE SAME PRICES.

MODEL: WHARTON EFA SCENARIO: HIGH GROWTH CASE*

YEAR:	1975 ACTUALS	1975.	1980.	1985.	1990.	2000.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	958.200	1114.800	1291.000	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	137.600	227.000	283.200	399.000	0.0
ENERGY	26.060	28.060	36.220	59.660	102.470	0.0
NONENERGY	109.740	109.740	190.780	223.540	296.330	0.0
GOVERNMENT EXPENDITURES	261.000	261.000	307.700	343.400	385.200	0.0
EXPORTS	90.630	90.600	113.200	155.200	192.500	0.0
IMPORTS	68.100	68.100	100.300	139.600	180.300	0.0
ENERGY	8.620	8.620	11.060	13.640	17.240	0.0
NONENERGY	59.480	59.480	55.140	126.460	165.560	0.0
GROSS NATIONAL PRODUCT	1191.700	1191.700	1499.900	1756.400	2084.900	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.300	0.0	124.930	139.860	179.390	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	98.630	105.280	109.650	0.0
ENERGY NONINTENSIVE MANUFACTURING		0.0	304.610	376.480	478.180	0.0
TRANSPORTATION	49.500	0.0	40.150	50.100	64.650	0.0
SERVICES	721.200	0.0	869.760	1033.830	1197.880	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1450.740	1694.030	2012.670	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	275.700	90.300	102.600	113.600	135.400	0.0
ENERGY INTENSIVE MANUFACTURING	362.300	84.700	105.500	120.800	143.300	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	185.300	249.500	302.400	384.300	0.0
TRANSPORTATION	81.900	46.500	63.900	78.400	99.300	0.0
SERVICES	935.200	734.200	917.000	1070.900	1246.400	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	1141.000	1436.800	1681.800	2000.100	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX [2]						
IMPLICIT GNP DEFLATOR	1.273	1.273	1.665	2.077	2.525	0.0
ENERGY PRICE		2.010	2.934	4.277	5.649	0.0
CAPITAL (INTEREST RATE)	1.066	1.070	1.550	2.020	2.760	0.0
LABOR	0.977	1.250	1.770	2.420	3.240	0.0
UNEMPLOYMENT RATE (%)	8.500	8.500	4.100	4.400	2.400	0.0
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS) [3]						
COAL	13.376	13.600	17.600	21.600	24.000	0.0
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL [4]	19.973	53.270	66.018	72.393	79.678	0.0
LWR	1.652	*	*	*	*	*
BREEDER		*	*	*	*	*
OTHER (FAST, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS) [4]	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	71.670	88.419	98.793	108.477	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) [5]	0.972	0.452	0.660	0.962	1.316	0.0

FOOTNOTES

- * VALUES NOT REPORTED FOR THIS MODEL
- 1 VALUES ARE REPORTED FOR YEARS 1975,1980,1985, AND 1990, RATHER THAN THE USUAL 1975,1985,1990,2000, AND 2010 BREAKDOWN.
- 2 PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00).
- 3 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE GROUPED TOGETHER AS ONE CATEGORY.
- 4 THE QUANTITY REPORTED FOR OIL AND GAS IS TOTAL SUPPLY. IMPORTS HAVE NOT BEEN DISTINGUISHED SEPARATELY.
- 5 PRIMARY FOSSIL FUEL PRICE IS BASED ON THE ENERGY PRICE INDEX WHERE 1.00 = $0.22 / MILLION BTU.

MODEL: HUDSON-JORGENSON
YEAR:

	SCENARIO: HIGH GROWTH CASE* 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	0.0	1259.100	1557.100	2325.100	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	269.000	350.500	524.400	0.0
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	376.500	463.900	677.500	0.0
EXPORTS	90.600	0.0	19.400	9.000	4.800	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1944.100	2370.500	3531.000	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.030	0.0	219.000	255.000	342.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	690.000	831.000	1233.000	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.500	0.0	51.000	61.000	86.000	0.0
SERVICES	721.200	0.0	1065.000	1329.000	2048.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	2025.000	2476.000	3709.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	349.000	403.000	523.000	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	0.0	1426.000	1740.000	2469.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	0.0	141.000	172.000	239.000	0.0
SERVICES	935.200	0.0	1760.000	2088.000	2999.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3616.000	4403.000	6230.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX[3]						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.496	3.281	6.880	0.0
CAPITAL (INTEREST RATE)	1.098	0.0	2.552	3.057	4.365	0.0
LABOR	0.977	0.0	2.711	3.649	6.553	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	0.0	26.600	31.900	46.700	0.0
NATURAL GAS	19.200	0.0	22.400	22.400	19.300	0.0
OIL AND NGL	19.573	0.0	30.000	30.200	24.800	0.0
LWR	1.652	0.0	12.200	20.100	38.900	0.0
LMFBR		*	*	*	*	*
OTHER (LWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	13.800	18.800	39.200	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	105.000	123.400	168.900	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	13.000	12.000	6.000	0.0
% COAL	44.500	0.0	53.000	45.000	40.000	0.0
% NUCLEAR	9.000	0.0	34.000	43.000	54.000	0.0
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	0.495	0.527	0.589	0.0
GAS ($/MCF)	0.760	0.0	1.564	1.603	1.776	0.0
OIL ($/BBL)	8.160	0.0	10.208	10.711	13.077	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	29.470	27.505	29.784	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	3.576	4.651	7.170	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	1.265	1.321	1.840	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

[1] VALUES ARE REPORTED FOR YEARS 1985,1990, AND 2000 ONLY.

[2] UNDER NONENERGY DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (ENERGY INTENSIVE AND NONINTENSIVE) IS AGGREGATED AS ONE CATEGORY.

[3] PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00); THE ENERGY PRICE INDEX IS FOR DELIVERED ENERGY.

[4] FOR THE HIGH GROWTH CASE, THE CONSTRAINED HIGH GROWTH CASE, AND THE CONSTRAINED BASE CASE, THE VALUE REPORTED FOR LWR UNDER DOMESTIC PRODUCTION INCLUDES HYDRO, OTHER ELECTRIC SOURCES, AND SHALE.

[5] FOR THE BASE CASE AND DECLINING OIL PRICE CASE, THE FOLLOWING CHANGES HAVE BEEN MADE IN REPORTING UNDER DOMESTIC ENERGY PRODUCTION:
- A) THE VALUE REPORTED FOR SOLAR HEATING AND COOLING IS ACTUALLY HYDROPOWER PRODUCTION.
- B) THE VALUE REPORTED FOR OTHER IS OTHER ELECTRICITY SOURCES.
- C) THE VALUE REPORTED FOR AES IS ACTUALLY SHALE PRODUCTION.

MODEL: HNYILICZA YEAR:	SCENARIO: HIGH GROWTH CASE* 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	*	*	*	*	*
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	*	*	*	*	*
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.030	*	*	*	*	*
EXPORTS	90.000	*	*	*	*	*
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	1422.797	1922.495	2294.884	3521.842	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	262.900	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	*	*	*	*	*
TOTAL NONENERGY FINAL DEMAND	1136.000	*	*	*	*	*
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	382.300	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	61.900	*	*	*	*	*
SERVICES	935.200	*	*	*	*	*
TOTAL NONENERGY GROSS OUTPUT	2213.200	*	*	*	*	*
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	0.998	1.367	1.592	2.087	0.0
ENERGY PRICE [1]		0.439	0.378	0.348	0.288	0.0
CAPITAL (INTEREST RATE)	1.086	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	*	*	*	*	*
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	*	*	*	*	*
LWR	1.652	*	*	*	*	*
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	76.600	104.500	123.800	182.400	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	16.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) [1]	0.972	0.439	0.378	0.348	0.288	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
[1] ENERGY PRICE IS IN 1972 $/MILLION BTU.

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MODEL:      BNL-HUDSON                              SCENARIO:  HIGH GROWTH CASE*
YEAR:                                                           1975 ACTUALS        1975.        1985.        1990.        2000.        2010.
                                                                ------------        -----        -----        -----        -----        -----
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)1
     CONSUMPTION                                                     770.300          0.0     1259.130     1557.100     2325.100          0.0
     GROSS PRIVATE DOMESTIC INVESTMENT                               137.800          0.0      269.000      350.500      524.400          0.0
       ENERGY                                                         28.000            *            *            *            *            *
       NONENERGY                                                     109.740            *            *            *            *            *
     GOVERNMENT EXPENDITURES                                         261.000          0.0      376.500      453.900      677.500          0.0
     EXPORTS                                                          90.600          0.0       19.400        9.000        4.000          0.0
     IMPORTS                                                          68.100            *            *            *            *            *
       ENERGY                                                          8.620            *            *            *            *            *
       NONENERGY                                                      59.480            *            *            *            *            *
     GROSS NATIONAL PRODUCT                                         1191.700          0.0     1944.100     2370.500     3531.800          0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)
     AGRICULTURE,NONFUEL MINING,CONSTRUCTION                         104.000          0.0      219.000      255.000      342.000          0.0
     ENERGY INTENSIVE MANUFACTURING                                  262.900          0.0      690.000      831.000     1233.000          0.0
     ENERGY NONINTENSIVE MANUFACTURING                                                  *            *            *            *            *
     TRANSPORTATION                                                   49.900          0.0       51.000       61.000       86.000          0.0
     SERVICES                                                        721.200          0.0     1065.000     1329.000     2048.000          0.0
     TOTAL NONENERGY FINAL DEMAND                                   1138.000          0.0     2025.000     2476.000     3709.000          0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)
     AGRICULTURE,NONFUEL MINING,CONSTRUCTION                         279.700          0.0      349.000      403.000      523.000          0.0
     ENERGY INTENSIVE MANUFACTURING                                  362.300          0.0     1426.000     1740.000     2449.000          0.0
     ENERGY NONINTENSIVE MANUFACTURING                               534.000            *            *            *            *            *
     TRANSPORTATION                                                   81.500          0.0      141.000      172.000      239.000          0.0
     SERVICES                                                        935.200          0.0     1700.000     2088.000     2959.000          0.0
     TOTAL NONENERGY GROSS OUTPUT                                   2213.200          0.0     3616.000     4403.000     6230.000          0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX
     IMPLICIT GNP DEFLATOR                                             1.273            *            *            *            *            *
     ENERGY PRICE                                                                     0.0        2.456        3.281        6.080          0.0
     CAPITAL (INTEREST RATE)                                           1.068          0.0        2.552        3.057        4.365          0.0
     LABOR                                                             0.977          0.0        2.711        3.649        6.553          0.0
     UNEMPLOYMENT RATE (%)                                             8.500            *            *            *            *            *
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)
     COAL                                                             13.376          0.0       22.930       30.430       42.310          0.0
     NATURAL GAS                                                      19.200          0.0       23.030       21.400       22.410          0.0
     OIL AND NGL                                                      19.573          0.0       29.400       29.200       24.000          0.0
     LWR                                                               1.652          0.0        6.150       12.900       25.500          0.0
     LMFBR                                                                            0.0          0.0          0.0        1.750          0.0
     OTHER (NUK. HIGH)                                                                  *            *            *            *            *
     SOLAR ELECTRIC                                                                   0.0        0.190        0.450        3.200          0.0
     SOLAR HEATING AND COOLING                                                        0.0        0.160        0.460        1.210          0.0
     OTHER (HYDRO, GEOTHERMAL, SHALE)                                  3.159          0.0        3.800        4.100        4.300          0.0
     ALTERNATIVE ENERGY SYSTEMS                                                       0.0        0.300        1.000        3.250          0.0
OIL AND GAS IMPORTS (QUADS)                                           13.719          0.0       17.040       23.560       40.170          0.0
TOTAL ENERGY INPUTS (QUADS)                                           71.078          0.0      105.000      123.400      148.900          0.0
ELECTRICITY GENERATION BY SOURCE
     % OIL AND GAS                                                    30.600          0.0       17.000       12.000        5.000          0.0
     % COAL                                                           44.500          0.0       49.000       49.000       42.000          0.0
     % NUCLEAR                                                         9.000            *            *            *            *            *
     % OTHER                                                          16.900          0.0       34.000       39.000       53.000          0.0
DOMESTIC PRICES (CONSTANT 1972 $)
     COAL ($/MILLION BTU)                                              0.630          0.0        0.495        0.527        0.589          0.0
     GAS ($/MCF)                                                       0.760          0.0        1.564        1.603        1.776          0.0
     OIL ($/BBL)                                                       8.160          0.0       10.216       10.711       13.877          0.0
     ELECTRICITY ($/1000 KWH)                                         21.220          0.0       28.134       27.890       27.285          0.0

TOTAL ELECTRICITY (TKWH)                                               1.917          0.0        3.145        4.029        6.233          0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **                      0.972          0.0        1.301        1.367        1.881          0.0



FOOTNOTES

*  VALUES NOT REPORTED FOR THIS MODEL
** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES
                AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)
1  THE NONENERGY SECTOR VALUES REPORTED ARE THE SAME AS IN THE HUDSON-JORGENSON
                RUNS. THE BROOKHAVEN MODEL HAS BEEN RUN WITH THESE VALUES TO
                OBTAIN GREATER ENERGY SECTOR DETAIL.
2  SEE THE FOOTNOTES FOR THE HUDSON-JORGENSON MODEL.
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MODEL: PILOT SCENARIO: HIGH GROWTH WITH CONSTRAINTS[1]

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	918.500	1515.000	1933.700	2950.200
GROSS PRIVATE DOMESTIC INVESTMENT[4]	137.800	114.602	601.729	480.676	929.107	336.276
ENERGY	28.060	7.602	43.530	53.776	54.907	64.676
NONENERGY	109.740	107.000	558.200	425.900	774.200	171.600
GOVERNMENT EXPENDITURES	261.000	261.000	318.400	547.200	622.700	980.800
EXPORTS[1]	90.600	22.500	0.0	0.0	0.0	0.0
IMPORTS	69.100	22.500	0.0	0.0	0.0	0.0
ENERGY	8.620	0.0	45.300	50.300	62.700	25.100
NONENERGY	59.480	0.0	45.300	50.300	62.700	25.100
GROSS NATIONAL PRODUCT[4]	1191.700	1169.402	1838.629	2643.775	3285.507	4257.273
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	13.100	12.800	13.000	12.900
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	10.200	10.500	10.600	11.000
ENERGY NONINTENSIVE MANUFACTURING		0.0	21.400	22.800	23.500	24.000
TRANSPORTATION	49.500	*	*	*	*	*
SERVICES	721.200	0.0	53.300	53.900	52.900	52.100
TOTAL NONENERGY FINAL DEMAND	1139.000	100.000	100.000	100.000	100.000	100.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	279.700	514.200	563.000	1016.200	1356.800
ENERGY INTENSIVE MANUFACTURING	382.300	382.300	601.000	763.600	1091.900	1454.700
ENERGY NONINTENSIVE MANUFACTURING	534.000	534.000	1033.300	1339.300	2084.700	2778.700
TRANSPORTATION	81.900	81.900	133.100	172.200	234.700	330.300
SERVICES	935.200	935.300	1447.300	1345.730	2511.500	3800.400
TOTAL NONENERGY GROSS OUTPUT	2213.200	2213.200	3728.930	4789.801	5929.000	9720.898
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE[3]		6.287	5.784	6.153	6.287	6.287
CAPITAL (INTEREST RATE)	1.088	*	*	*	*	*
LABOR	0.577	*	*	*	*	*
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	14.860	24.940	30.400	40.000	45.800
NATURAL GAS	19.200	21.050	21.390	25.600	23.790	8.710
OIL AND NGL	19.973	20.750	26.750	31.490	33.790	13.990
LWR	1.652	2.150	4.140	4.140	4.140	4.140
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.155	2.840	3.800	4.730	6.550	11.280
ALTERNATIVE ENERGY SYSTEMS[4]		3.590	11.750	21.700	50.040	150.620
OIL AND GAS IMPORTS (QUADS)	13.719	7.980	20.000	20.000	20.000	7.000
TOTAL ENERGY INPUTS (QUADS)	71.073	73.320	112.770	138.060	178.310	241.540
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	27.660	39.320	35.730	42.960	59.940
% COAL	44.500	41.890	31.320	42.730	40.010	28.230
% NUCLEAR	9.000	12.870	15.450	10.840	7.970	5.100
% OTHER	15.900	17.570	13.900	10.650	9.070	6.730
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	103.700	0.780	5.370	6.750	4.410
GAS ($/MCF)	0.780	103.700	6.230	5.540	6.750	4.410
OIL ($/BBL)	3.160	537.250	21.250	27.110	32.630	21.360
ELECTRICITY ($/1000 KWH)	21.220	1219.060	112.450	73.500	86.180	64.650
TOTAL ELECTRICITY (TKWH)	1.917	1.620	2.590	3.690	5.020	7.850
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	98.487	1.935	5.106	6.296	4.116

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 NUMBER REPORTED IS NET EXPORTS.

2 NONENERGY FINAL DEMAND COMPOSITION IS REPORTED BY PERCENTAGE BREAKDOWNS RATHER THAN DOLLAR AMOUNTS. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

3 ENERGY PRICE IS BASED EITHER ON SHADOW PRICES OR THE PRICE OF ENERGY IN TERMS OF INVESTMENT DOLLARS NEEDED FOR AES.

4 INVESTMENT FOR AES IS NOT INCLUDED UNDER GROSS PRIVATE DOMESTIC INVESTMENT, ENERGY INVESTMENT, OR GNP.

MODEL: KENNEDY - NIEMEYER SCENARIO: HIGH GROWTH WITH CONSTRAINTS'

YEAR:	1975 ACTUALS	1971.[1]	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	692.000	1079.000	1243.000	1655.000	2108.000
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	161.000	260.000	304.000	421.000	557.000
ENERGY	28.000	30.000	81.000	90.000	118.000	182.000
NONENERGY	109.740	131.000	179.000	214.000	303.000	375.000
GOVERNMENT EXPENDITURES	261.000	238.000	386.000	451.000	626.800	826.000
EXPORTS	90.600	68.000	200.000	260.000	445.000	741.000
IMPORTS	68.100	68.000	124.000	147.000	212.800	292.000
ENERGY	8.620	62.000	98.000	117.000	170.800	236.000
NONENERGY	59.400	6.000	26.000	30.000	42.000	56.000
GROSS NATIONAL PRODUCT	1191.700	1090.000	1802.000	2110.000	2934.000	3941.000
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	131.000	212.000	247.000	342.000	451.000
ENERGY INTENSIVE MANUFACTURING	262.900	354.000	652.000	779.000	1136.800	1613.000
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	573.000	905.000	1046.000	1409.000	1817.000
TOTAL NONENERGY FINAL DEMAND	1138.000	1058.000	1769.000	2072.000	2886.000	3880.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	274.000	338.000	396.000	551.800	736.000
ENERGY INTENSIVE MANUFACTURING	382.300	695.000	1260.000	1486.000	2143.000	3007.000
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	941.000	1516.000	1763.000	2408.800	3164.000
TOTAL NONENERGY GROSS OUTPUT	2213.200	1841.000	3104.000	3644.000	5102.800	6907.000
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE[3]		0.670	1.740	2.130	3.150	4.000
CAPITAL (INTEREST RATE)	1.000	0.960	1.000	0.950	0.880	0.840
LABOR	0.977	0.980	1.170	1.270	1.400	1.550
UNEMPLOYMENT RATE (%)	6.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	13.140	20.630	27.090	43.100	62.120
NATURAL GAS	19.290	*	*	*	*	*
OIL AND NGL	19.473	46.170	25.110	27.210	34.890	47.940
LWR	1.652	0.320	7.220	6.230	4.660	3.480
LMFBR		*	*	*	*	*
OTHER (MHR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	2.580	2.740	2.750	2.800	2.830
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[5]	13.719	7.210	54.100	64.090	88.610	114.310
TOTAL ENERGY INPUTS (QUADS)	71.078	69.440	109.800	127.380	174.060	230.670
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	39.000	17.000	12.000	7.800	4.000
% COAL	44.500	43.000	45.000	58.000	75.000	85.000
% NUCLEAR	9.000	2.000	28.000	20.000	11.000	6.000
% OTHER	15.900	16.000	10.000	9.000	7.000	5.000
DOMESTIC PRICES (CONSTANT 1972 $)[6]						
COAL ($/MILLION BTU)	0.630	0.340	1.560	2.710	5.860	6.590
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	3.720	16.510	19.740	27.810	38.200
ELECTRICITY ($/1000 KWH)	21.220	17.800	27.800	34.000	54.500	63.100
TOTAL ELECTRICITY (TKWH)	1.917	1.614	2.612	3.040	4.161	5.487
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.575	2.580	3.513	5.744	7.360

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 VALUES ARE REPORTED FOR 1971 INSTEAD OF 1975.

2 UNDER NONENERGY FINAL DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (BOTH ENERGY INTENSIVE AND ENERGY NONINTENSIVE) IS REPORTED AS A SINGLE AGGREGATE VALUE. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

3 PRICES ARE REPORTED AS INDICES WITH 1975 AS BASE (1.00).

4 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE COMBINED AS ONE CATEGORY. ALL NUCLEAR TYPES ARE GROUPED AS ONE CATEGORY; SOLAR ELECTRIC, SOLAR HEATING AND COOLING, AND OTHER ARE REPORTED TOGETHER.

5 OIL AND GAS IMPORTS INCLUDE AES.

6 UNDER DOMESTIC PRICES, GAS AND OIL ARE ASSUMED TO HAVE THE SAME PRICES.

MODEL: HUDSON-JORGENSON SCENARIO: HIGH GROWTH WITH CONSTRAINTS5

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	0.0	1217.700	1495.100	2214.700	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	277.900	332.800	488.100	0.0
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	376.500	453.900	677.900	0.0
EXPORTS	90.600	0.0	19.300	9.000	4.000	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1891.600	2291.000	3384.800	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)2						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	213.000	246.000	325.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	670.000	796.000	1171.800	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.500	0.0	49.000	58.000	81.000	0.0
SERVICES	721.200	0.0	1048.000	1300.000	1951.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1989.000	2400.000	3568.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)2						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	340.000	390.000	494.800	0.0
ENERGY INTENSIVE MANUFACTURING	382.200	0.0	1381.000	1669.000	2331.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	0.0	136.000	164.000	227.000	0.0
SERVICES	935.200	0.0	1670.000	2036.000	2891.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	0.0	3527.000	4259.000	5943.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX 3						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	3.159	4.205	7.911	0.0
CAPITAL (INTEREST RATE)	1.088	0.0	2.552	3.057	4.365	0.0
LABOR	0.977	0.0	2.669	3.519	6.430	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)4						
COAL	13.376	0.0	20.400	25.600	38.100	0.0
NATURAL GAS	19.200	0.0	22.400	22.400	19.300	0.0
OIL AND NGL	19.973	0.0	30.000	30.200	24.800	0.0
LWR	1.652	0.0	12.000	19.100	36.700	0.0
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	4.700	5.700	18.800	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	89.500	103.200	137.700	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	19.000	15.000	7.000	0.0
% COAL	44.500	0.0	60.000	44.000	39.000	0.0
% NUCLEAR	9.000	0.0	32.000	41.000	54.000	0.0
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	1.281	1.312	1.375	0.0
GAS ($/MCF)	0.760	0.0	2.373	2.420	2.893	0.0
OIL ($/BBL)	8.160	0.0	14.546	15.332	17.415	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	32.141	30.177	32.456	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	3.465	4.352	6.757	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.0	2.101	2.177	2.384	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 VALUES ARE REPORTED FOR YEARS 1985,1990, AND 2000 ONLY.

2 UNDER NONENERGY DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (ENERGY INTENSIVE AND NONINTENSIVE) IS AGGREGATED AS ONE CATEGORY.

3 PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00); THE ENERGY PRICE INDEX IS FOR DELIVERED ENERGY.

4 FOR THE HIGH GROWTH CASE, THE CONSTRAINED HIGH GROWTH CASE, AND THE CONSTRAINED BASE CASE, THE VALUE REPORTED FOR LWR UNDER DOMESTIC PRODUCTION INCLUDES HYDRO, OTHER ELECTRIC SOURCES, AND SHALE.

5 FOR THE BASE CASE AND DECLINING OIL PRICE CASE, THE FOLLOWING CHANGES HAVE BEEN MADE IN REPORTING UNDER DOMESTIC ENERGY PRODUCTION:
- A) THE VALUE REPORTED FOR SOLAR HEATING AND COOLING IS ACTUALLY HYDROPOWER PRODUCTION.
- B) THE VALUE REPORTED FOR OTHER IS OTHER ELECTRICITY SOURCES.
- C) THE VALUE REPORTED FOR AES IS ACTUALLY SHALE PRODUCTION.

MODEL: HNYILICZA YEAR:	SCENARIO: HIGH GROWTH WITH CONSTRAINTS* 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	*	*	*	*	*
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	*	*	*	*	*
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	*	*	*	*	*
EXPORTS	90.600	*	*	*	*	*
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	1306.507	1733.273	2034.514	2927.642	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	262.900	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	*	*	*	*	*
TOTAL NONENERGY FINAL DEMAND	1138.000	*	*	*	*	*
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	362.300	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	*	*	*	*	*
TOTAL NONENERGY GROSS OUTPUT	2213.200	*	*	*	*	*
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	0.971	1.354	1.579	2.081	0.0
ENERGY PRICE 1		0.802	0.621	0.560	0.439	0.0
CAPITAL (INTEREST RATE)	1.068	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	*	*	*	*	*
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	*	*	*	*	*
LWR	1.652	*	*	*	*	*
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	56.500	80.200	95.400	135.800	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) 1	0.972	0.802	0.621	0.560	0.439	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
1 ENERGY PRICE IS IN 1972 $/MILLION BTU.

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MODEL:       BNL-BESOM                         SCENARIO:  HIGH GROWTH WITH CONSTRAINTS*
YEAR:                                                       1975 ACTUALS     1975.       1985.       1990.       2000.     2010.
                                                            ------------     -----       -----       -----       -----     -----
MACROECONOMIC ACTIVITY (CONSTANT 1972 $) 1
     CONSUMPTION                                                 770.300       0.0    1217.700    1495.100    2214.700       0.0
     GROSS PRIVATE DOMESTIC INVESTMENT                           137.800       0.0     277.900     332.800     488.100       0.0
       ENERGY                                                     28.060        *           *           *           *         *
       NONENERGY                                                 109.740        *           *           *           *         *
     GOVERNMENT EXPENDITURES                                     261.000       0.0     376.500     453.900     677.900       0.0
     EXPORTS                                                      90.600       0.0      19.300       9.000       4.000       0.0
     IMPORTS                                                      68.100        *           *           *           *         *
       ENERGY                                                      8.620        *           *           *           *         *
       NONENERGY                                                  59.480        *           *           *           *         *
     GROSS NATIONAL PRODUCT                                     1191.700       0.0    1891.500    2291.000    3384.800       0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)
     AGRICULTURE,NONFUEL MINING,CONSTRUCTION                     104.000       0.0     213.000     246.000     325.000       0.0
     ENERGY INTENSIVE MANUFACTURING                              262.900       0.0     670.000     796.000    1171.400       0.0
     ENERGY NONINTENSIVE MANUFACTURING                                          *           *           *           *         *
     TRANSPORTATION                                               49.900       0.0      49.000      58.000      81.000       0.0
     SERVICES                                                    721.200       0.0    1048.000    1300.000    1991.000       0.0
     TOTAL NONENERGY FINAL DEMAND                               1138.000       0.0    1980.000    2400.000    3568.800       0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)
     AGRICULTURE,NONFUEL MINING,CONSTRUCTION                     279.700       0.0     340.000     350.000     494.000       0.0
     ENERGY INTENSIVE MANUFACTURING                              382.300       0.0    1381.000    1669.000    2331.000       0.0
     ENERGY NONINTENSIVE MANUFACTURING                           534.000        *           *           *           *         *
     TRANSPORTATION                                               81.900       0.0     136.000     164.000     227.000       0.0
     SERVICES                                                    935.200       0.0    1670.000    2036.000    2891.000       0.0
     TOTAL NONENERGY GROSS OUTPUT                               2213.200       0.0    3527.000    4259.000    5943.000       0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX
     IMPLICIT GNP DEFLATOR                                         1.273        *           *           *           *         *
     ENERGY PRICE                                                             0.0       3.159       4.205       7.511       0.0
     CAPITAL (INTEREST RATE)                                       1.068       0.0       2.552       3.057       4.365       0.0
     LABOR                                                         0.977       0.0       2.669       3.519       6.430       0.0
     UNEMPLOYMENT RATE (%)                                         8.500        *           *           *           *         *
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)
     COAL                                                         13.376       0.0      18.160      25.590      33.620       0.0
     NATURAL GAS                                                  19.200       0.0      23.030      21.400      20.500       0.0
     OIL AND NGL                                                  19.973       0.0      29.700      30.200      24.800       0.0
     LWR                                                           1.652       0.0       8.000      11.000      24.000       0.0
     LMFBR                                                                    0.0         0.0         0.0       1.550       0.0
     OTHER (HWR, HTGR)                                                         *           *           *           *         *
     SOLAR ELECTRIC                                                           0.0       0.190       0.450       3.200       0.0
     SOLAR HEATING AND COOLING                                                0.0       0.180       0.510       1.120       0.0
     OTHER (HYDRO, GEOTHERMAL, SHALE)                              3.159       0.0       3.800       4.100       4.300       0.0
     ALTERNATIVE ENERGY SYSTEMS                                               0.0       0.300       1.000       3.000       0.0
OIL AND GAS IMPORTS (QUADS)                                       13.719       0.0       6.130       8.950      21.520       0.0
TOTAL ENERGY INPUTS (QUADS)                                       71.078       0.0      89.500     103.200     137.700       0.0
ELECTRICITY GENERATION BY SOURCE
     % OIL AND GAS                                                30.630       0.0      20.000      13.000       6.000       0.0
     % COAL                                                       44.500       0.0      43.000      47.000      37.000       0.0
     % NUCLEAR                                                     9.000        *           *           *           *         *
     % OTHER                                                      15.500       0.0      37.000      40.000      57.000       0.0
DOMESTIC PRICES (CONSTANT 1972 $)
     COAL ($/MILLION BTU)                                          0.630       0.0       1.281       1.312       1.375       0.0
     GAS ($/MCF)                                                   0.780       0.0       2.373       2.420       2.593       0.0
     OIL ($/BBL)                                                   6.160       0.0      14.546      15.332      17.415       0.0
     ELECTRICITY ($/1000 KWH)                                     21.220       0.0      30.782      30.460      29.619       0.0

TOTAL ELECTRICITY (TKWH)                                           1.917       0.0       2.798       3.569       5.545       0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **                  0.972       0.0       2.127       2.204       2.415       0.0


FOOTNOTES

*   VALUES NOT REPORTED FOR THIS MODEL
**  THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES
                AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)
1   THE NONENERGY SECTOR NUMBERS REPORTED ARE THE SAME AS IN THE HUDSON-JORGENSON
                RUNS. THE BROOKHAVEN MODEL HAS BEEN RUN WITH THESE VALUES TO
                OBTAIN GREATER ENERGY SECTOR DETAIL.
2   SEE THE FOOTNOTES FOR THE HUDSON-JORGENSON MODEL.
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MODEL:      PILOT                                        SCENARIO:  BASE CASE WITH CONSTRAINTS*
YEAR:                                                                 1975 ACTUALS         1975.         1985.         1990.         2000.         2010.
                                                                      ------------         -----         -----         -----         -----         -----
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)
    CONSUMPTION                                                           770.300        770.300      1073.190      1350.600      1551.100      2138.800
    GROSS PRIVATE DOMESTIC INVESTMENT 4                                   137.800        114.602       278.180       305.922       574.616       228.279
      ENERGY                                                               28.060          7.602        28.180        41.222        44.116        25.678
      NONENERGY                                                           109.740        107.000       250.000       265.700       530.500       202.600
    GOVERNMENT EXPENDITURES                                               261.000        261.000       371.500       467.600       537.000       740.500
    EXPORTS 1                                                              90.600         22.500         0.0           0.0           0.0           0.0
    IMPORTS                                                                68.100         22.500         0.0           0.0           0.0           0.0
      ENERGY                                                                9.620          0.0          43.500        50.300        62.700        56.500
      NONENERGY                                                            59.480          0.0          43.500        50.300        62.700        56.500
    GROSS NATIONAL PRODUCT 4                                             1191.700       1169.402      1722.760      2125.122      2662.716      3107.578
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $) 2
    AGRICULTURE,NONFUEL MINING,CONSTRUCTION                               104.000          0.0          13.200        13.390        12.900        12.800
    ENERGY INTENSIVE MANUFACTURING                                        262.900          0.0          10.200        10.000        10.400        10.600
    ENERGY NONINTENSIVE MANUFACTURING                                                      0.0          23.200        23.500        23.300        23.800
    TRANSPORTATION                                                         49.500          *             *             *             *             *
    SERVICES                                                              721.200          0.0          53.400        53.200        53.500        52.800
    TOTAL NONENERGY FINAL DEMAND                                         1138.000        100.000       100.000       100.000       100.000       100.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)
    AGRICULTURE,NONFUEL MINING,CONSTRUCTION                               279.700        279.700       437.000       520.100       739.400       912.600
    ENERGY INTENSIVE MANUFACTURING                                        382.300        362.300       540.900       644.300       842.000      1022.400
    ENERGY NONINTENSIVE MANUFACTURING                                     534.000        534.000       658.050      1015.600      1493.500      1656.300
    TRANSPORTATION                                                         81.900         81.900       121.400       148.300       177.390       231.800
    SERVICES                                                              935.200        935.300      1350.900      1638.900      2039.400      2720.700
    TOTAL NONENERGY GROSS OUTPUT                                         2213.200       2213.200      3308.100      3967.300      5290.602      6743.801
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX
    IMPLICIT GNP DEFLATOR                                                   1.273          *             *             *             *             *
    ENERGY PRICE 3                                                                         6.287         4.919         6.098         6.287         6.287
    CAPITAL (INTEREST RATE)                                                 1.088          *             *             *             *             *
    LABOR                                                                   0.977          *             *             *             *             *
    UNEMPLOYMENT RATE (%)                                                   8.500          *             *             *             *             *
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)
    COAL                                                                   13.376         14.860        25.800        30.400        40.000        45.800
    NATURAL GAS                                                            19.200         21.050        21.070        25.270        23.990         8.780
    OIL AND NGL                                                            19.973         20.750        24.960        29.700        34.870        14.390
    LWR                                                                     1.652          2.150         4.140         4.140         4.140         4.140
    LMFBR                                                                                  *             *             *             *             *
    OTHER (HWR, HTGR)                                                                      *             *             *             *             *
    SOLAR ELECTRIC                                                                         *             *             *             *             *
    SOLAR HEATING AND COOLING                                                              *             *             *             *             *
    OTHER (HYDRO, GEOTHERMAL, SHALE)                                        3.159          2.840         3.800         4.730         6.550        11.280
    ALTERNATIVE ENERGY SYSTEMS                                                             3.690         4.950         5.850        16.190        77.960
OIL AND GAS IMPORTS (QUADS)                                                13.719          7.990        19.200        20.000        29.000        15.770
TOTAL ENERGY INPUTS (QUADS)                                                71.078         73.320       103.920       120.090       145.740       178.120
ELECTRICITY GENERATION BY SOURCE
    % OIL AND GAS                                                          30.600         27.620        18.780        20.196        21.760        36.840
    % COAL                                                                 44.500         41.920        51.410        54.950        57.640        47.090
    % NUCLEAR                                                               9.000         12.880        15.690        12.540         9.640         6.930
    % OTHER                                                                15.900         17.590        14.120        12.320        10.960         9.140
DOMESTIC PRICES (CONSTANT 1972 $)
    COAL ($/MILLION BTU)                                                    0.630         77.410         1.520         5.370         6.740         4.400
    GAS ($/MCF)                                                             0.740         77.410         6.120         5.580         6.740         4.400
    OIL ($/BBL)                                                             8.160        401.160        17.410        27.300        32.560        21.290
    ELECTRICITY ($/1000 KWH)                                               21.220        909.430        94.700        73.040        86.110        64.510

TOTAL ELECTRICITY (TKWH)                                                    1.917          1.620         2.550         3.190         4.150         5.780
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **                           0.572         71.526         2.533         5.125         6.295         4.105


FOOTNOTES

*  VALUES NOT REPORTED FOR THIS MODEL
** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES
                  AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)
1  NUMBER REPORTED IS NET EXPORTS.
2  NONENERGY FINAL DEMAND COMPOSITION IS REPORTED BY PERCENTAGE BREAKDOWNS
                  RATHER THAN DOLLAR AMOUNTS. THE VALUE REPORTED FOR SERVICES
                  INCLUDES TRANSPORTATION.
3  ENERGY PRICE IS BASED EITHER ON SHADOW PRICES OR THE PRICE OF ENERGY IN TERMS
                  OF INVESTMENT DOLLARS NEEDED FOR AES.
4  INVESTMENT FOR AES IS NOT INCLUDED UNDER GROSS PRIVATE DOMESTIC INVESTMENT,
                  ENERGY INVESTMENT, OR GNP.
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MODEL: KENNEDY - NIEMEYER SCENARIO: BASE CASE WITH CONSTRAINTS

YEAR:	1975 ACTUALS	1971.[1]	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	692.000	1006.000	1134.000	1396.000	1652.000
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	161.000	242.000	276.000	350.000	426.000
ENERGY	28.060	30.000	73.000	70.000	71.000	96.000
NONENERGY	109.740	131.000	169.000	206.000	279.000	330.000
GOVERNMENT EXPENDITURES	261.000	238.000	359.000	409.000	516.000	629.000
EXPORTS	90.600	68.000	186.000	237.000	374.000	576.000
IMPORTS	68.100	68.000	115.000	134.000	176.000	226.000
ENERGY	8.620	62.000	91.000	106.000	141.000	183.000
NONENERGY	59.480	6.000	24.000	28.000	35.000	43.000
GROSS NATIONAL PRODUCT	1191.700	1090.000	1679.000	1923.000	2460.000	3057.000
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	131.000	198.000	225.000	284.000	346.000
ENERGY INTENSIVE MANUFACTURING	262.900	354.000	607.000	710.000	950.000	1245.000
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.990	*	*	*	*	*
SERVICES	721.200	573.000	843.000	954.000	1184.000	1417.000
TOTAL NONENERGY FINAL DEMAND	1138.000	1058.000	1648.000	1889.000	2419.000	3008.000
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)[2]						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	204.000	315.000	360.000	459.000	566.000
ENERGY INTENSIVE MANUFACTURING	382.300	695.000	1164.000	1355.000	1794.000	2322.000
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	*	*	*	*	*
SERVICES	935.200	941.000	1413.000	1607.000	2022.000	2462.000
TOTAL NONENERGY GROSS OUTPUT	2213.200	1841.000	2892.000	3322.000	4275.000	5350.000
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE[3]		0.670	1.720	2.030	2.700	3.420
CAPITAL (INTEREST RATE)	1.086	0.960	1.000	0.970	0.910	0.890
LABOR	0.977	0.980	1.100	1.180	1.320	1.450
UNEMPLOYMENT RATE (4)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[4]						
COAL	13.376	13.140	19.180	24.460	35.550	47.490
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	46.170	23.550	25.120	30.830	39.680
LWR	1.652	0.320	6.360	5.510	4.100	3.050
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SPACE)	3.159	2.580	2.710	2.730	2.760	2.770
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[5]	13.719	7.210	50.400	58.350	73.420	87.160
TOTAL ENERGY INPUTS (QUADS)	71.078	69.440	102.230	116.170	146.660	180.150
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	39.000	18.000	13.000	8.000	5.000
% COAL	44.500	43.000	45.000	57.000	72.000	82.000
% NUCLEAR	9.000	2.000	26.000	20.000	12.000	7.000
% OTHER	15.900	16.000	11.000	10.000	8.000	6.000
DOMESTIC PRICES (CONSTANT 1972 $)[6]						
COAL ($/MILLION BTU)	0.630	0.340	1.330	1.970	2.900	2.950
GAS ($/MCF)	0.760	*	*	*	*	*
OIL ($/BBL)	8.160	3.720	16.500	19.690	27.630	37.660
ELECTRICITY ($/1000 KWH)	21.220	17.800	26.800	30.600	37.300	39.300
TOTAL ELECTRICITY (TKWH)	1.917	1.614	2.434	2.772	3.497	4.271
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.972	0.575	2.472	3.109	4.401	5.604

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

1 VALUES ARE REPORTED FOR 1971 INSTEAD OF 1975.

2 UNDER NONENERGY FINAL DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (BOTH ENERGY INTENSIVE AND ENERGY NONINTENSIVE) IS REPORTED AS A SINGLE AGGREGATE VALUE. THE VALUE REPORTED FOR SERVICES INCLUDES TRANSPORTATION.

3 PRICES ARE REPORTED AS INDICES WITH 1975 AS BASE (1.00).

4 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE COMBINED AS ONE CATEGORY. ALL NUCLEAR TYPES ARE GROUPED AS ONE CATEGORY; SOLAR ELECTRIC, SOLAR HEATING AND COOLING, AND OTHER ARE REPORTED TOGETHER.

5 OIL AND GAS IMPORTS INCLUDE AES.

6 UNDER DOMESTIC PRICES, GAS AND OIL ARE ASSUMED TO HAVE THE SAME PRICES.

MODEL: WHARTON EFA

SCENARIO: BASE CASE WITH CONSTRAINTS[1]

YEAR:	1975 ACTUALS	1975.	1980.	1985.	1990.	2000.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	770.300	913.100	1073.500	0.0	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.600	137.800	194.300	237.600	0.0	0.0
ENERGY	26.060	28.060	29.050	26.010	0.0	0.0
NONENERGY	109.740	109.740	165.250	211.590	0.0	0.0
GOVERNMENT EXPENDITURES	261.000	261.900	302.700	338.400	0.0	0.0
EXPORTS	90.600	90.600	107.000	184.100	0.0	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	8.620	10.310	12.890	0.0	0.0
NONENERGY	59.400	59.480	88.790	119.810	0.0	0.0
GROSS NATIONAL PRODUCT	1191.700	1191.730	1418.890	1671.000	0.0	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	109.550	109.800	0.0	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	92.750	103.310	0.0	0.0
ENERGY NONINTENSIVE MANUFACTURING		0.0	284.270	385.390	0.0	0.0
TRANSPORTATION	49.900	0.0	38.240	48.230	0.0	0.0
SERVICES	721.200	0.0	854.210	1002.300	0.0	0.0
TOTAL NONENERGY FINAL DEMAND	1136.000	0.0	1372.630	1613.440	0.0	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	90.300	90.200	95.200	0.0	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	84.700	100.000	116.700	0.0	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	185.300	229.900	282.600	0.0	0.0
TRANSPORTATION	81.900	46.500	60.900	74.900	0.0	0.0
SERVICES	935.230	734.200	879.800	1035.100	0.0	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.200	1141.000	1360.400	1603.100	0.0	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX[2]						
IMPLICIT GNP DEFLATOR	1.273	1.273	1.901	2.409	0.0	0.0
ENERGY PRICE		2.010	7.125	7.613	0.0	0.0
CAPITAL (INTEREST RATE)	1.088	1.070	1.850	2.540	0.0	0.0
LABOR	0.977	1.250	1.910	2.720	0.0	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)[3]						
COAL	15.376	13.600	9.200	12.000	0.0	0.0
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL[4]	19.573	53.270	61.921	67.384	0.0	0.0
LWR	1.652	*	*	*	*	*
BREEDER		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)[4]	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.078	71.670	75.921	84.184	0.0	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU)[5]	0.972	0.452	1.603	1.713	0.0	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

1 VALUES ARE REPORTED FOR YEARS 1975,1980,1985, AND 1990, RATHER THAN THE USUAL 1975,1985,1990,2000, AND 2010 BREAKDOWN.

2 PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00).

3 UNDER DOMESTIC ENERGY PRODUCTION, NATURAL GAS, OIL AND NGL ARE GROUPED TOGETHER AS ONE CATEGORY.

4 THE QUANTITY REPORTED FOR OIL AND GAS IS TOTAL SUPPLY. IMPORTS HAVE NOT BEEN DISTINGUISHED SEPARATELY.

5 PRIMARY FOSSIL FUEL PRICE IS BASED ON THE ENERGY PRICE INDEX WHERE 1.00 = $0.22 / MILLION BTU.

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MODEL:     HUDSON-JORGENSEN                    SCENARIO:  BASE CASE WITH CONSTRAINTS'
YEAR:                                                      1975 ACTUALS      1975.        1985.        1990.        2000.        2010.
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MACROECONOMIC ACTIVITY (CONSTANT 1972 $)
     CONSUMPTION                                               770.300        0.0      1110.000     1285.400     1722.400        0.0
     GROSS PRIVATE DOMESTIC INVESTMENT                         137.800        0.0       254.300      286.300      376.300        0.0
       ENERGY                                                   28.060         *            *            *            *            *
       NONENERGY                                               139.740         *            *            *            *            *
     GOVERNMENT EXPENDITURES                                   261.000        0.0       344.600      408.000      867.000        0.0
     EXPORTS                                                    90.600        0.0        19.500        9.100        5.300        0.0
     IMPORTS                                                    68.100         *            *            *            *            *
       ENERGY                                                    8.620         *            *            *            *            *
       NONENERGY                                                59.480         *            *            *            *            *
     GROSS NATIONAL PRODUCT                                   1191.700        0.0      1728.300     1988.700     2671.000        0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)2
     AGRICULTURE,NONFUEL MINING,CONSTRUCTION                   104.000        0.0       198.000      220.000      267.400        0.0
     ENERGY INTENSIVE MANUFACTURING                            262.900        0.0       609.000      691.000      913.000        0.0
     ENERGY NONINTENSIVE MANUFACTURING                                         *            *            *            *            *
     TRANSPORTATION                                             49.900        0.0        46.000       51.000       64.000        0.0
     SERVICES                                                  721.200        0.0       953.000     1125.000     1557.800        0.0
     TOTAL NONENERGY FINAL DEMAND                             1138.000        0.0      1806.000     2087.000     2801.000        0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)2
     AGRICULTURAL,NONFUEL MINING,CONSTRUCTION                  279.700        0.0       318.000      349.000      425.000        0.0
     ENERGY INTENSIVE MANUFACTURING                            362.300        0.0      1264.000     1451.000     1908.000        0.0
     ENERGY NONINTENSIVE MANUFACTURING                         534.000         *            *            *            *            *
     TRANSPORTATION                                             61.900        0.0       125.000      143.000      187.000        0.0
     SERVICES                                                  935.200        0.0      1632.000     1784.000     2396.400        0.0
     TOTAL NONENERGY GROSS OUTPUT                             2213.200        0.0      3239.000     3727.000     4916.400        0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX 3
     IMPLICIT GNP DEFLATOR                                       1.273         *            *            *            *            *
     ENERGY PRICE                                                             0.0         2.839        3.627        6.367        0.0
     CAPITAL (INTEREST RATE)                                     1.088        0.0         2.272        2.645        3.532        0.0
     LABOR                                                       0.977        0.0         2.352        2.914        4.461        0.0
     UNEMPLOYMENT RATE (%)                                       8.500         *            *            *            *            *
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)4
     COAL                                                       13.376        0.0        18.000       21.000       27.000        0.0
     NATURAL GAS                                                19.200        0.0        22.400       22.400       19.300        0.0
     OIL AND NGL                                                19.973        0.0        30.000       30.200       24.800        0.0
     LWR                                                         1.652        0.0        11.600       18.100       34.300        0.0
     LMFBR                                                                     *            *            *            *            *
     OTHER (HWR, HTGR)                                                         *            *            *            *            *
     SOLAR ELECTRIC                                                            *            *            *            *            *
     SOLAR HEATING AND COOLING                                                 *            *            *            *            *
     OTHER (HYDRO, GEOTHERMAL, SHALE)                            3.159         *            *            *            *            *
     ALTERNATIVE ENERGY SYSTEMS                                                *            *            *            *            *
OIL AND GAS IMPORTS (QUADS)                                     13.719        0.0         2.200        0.900        9.200        0.0
TOTAL ENERGY INPUTS (QUADS)                                     71.078        0.0        84.200       92.600      114.700        0.0
ELECTRICITY GENERATION BY SOURCE
     % OIL AND GAS                                              30.600        0.0        18.000       13.000        7.000        0.0
     % COAL                                                     44.500        0.0        46.000       41.000       30.000        0.0
     % NUCLEAR                                                   9.000        0.0        36.000       46.000       64.000        0.0
     % OTHER                                                    15.900         *            *            *            *            *
DOMESTIC PRICES (CONSTANT 1972 $)
     COAL ($/MILLION BTU)                                        0.630        0.0         1.265        1.289        1.344        0.0
     GAS ($/MCF)                                                 0.789        0.0         2.373        2.420        2.593        0.0
     OIL ($/BBL)                                                 8.160        0.0        14.546       15.049       17.415        0.0
     ELECTRICITY ($/1000 KWH)                                   21.220        0.0        32.063       30.098       32.934        0.0

TOTAL ELECTRICITY (TKWH)                                         1.917        0.0         3.210        3.919        5.354        0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **                0.972        0.0         2.125        2.181        2.414        0.0



FOOTNOTES

*  VALUES NOT REPORTED FOR THIS MODEL
** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES
                 AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)
1  VALUES ARE REPORTED FOR YEARS 1985,1990, AND 2000 ONLY.
2  UNDER NONENERGY DEMAND COMPOSITION AND GROSS OUTPUT, MANUFACTURING (ENERGY
                 INTENSIVE AND NONINTENSIVE) IS AGGREGATED AS ONE CATEGORY.
3  PRICES ARE REPORTED AS INDICES WITH 1972 AS BASE (1.00); THE ENERGY PRICE
                 INDEX IS FOR DELIVERED ENERGY.
4  FOR THE HIGH GROWTH CASE, THE CONSTRAINED HIGH GROWTH CASE, AND THE
                 CONSTRAINED BASE CASE, THE VALUE REPORTED FOR LWR UNDER
                 DOMESTIC PRODUCTION INCLUDES HYDRO, OTHER ELECTRIC SOURCES,
                 AND SHALE.
5  FOR THE BASE CASE AND DECLINING OIL PRICE CASE, THE FOLLOWING CHANGES HAVE
                 BEEN MADE IN REPORTING UNDER DOMESTIC ENERGY PRODUCTION:
                         A)  THE VALUE REPORTED FOR SOLAR HEATING AND
                             COOLING IS ACTUALLY HYDROPOWER PRODUCTION.
                         B)  THE VALUE REPORTED FOR OTHER IS OTHER
                             ELECTRICITY SOURCES.
                         C)  THE VALUE REPORTED FOR AES IS ACTUALLY SHALE
                             PRODUCTION.
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MODEL: HNYILICZA YEAR:	SCENARIO: BASE CASE WITH CONSTRAINTS' 1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)						
CONSUMPTION	770.300	*	*	*	*	*
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	*	*	*	*	*
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	*	*	*	*	*
EXPORTS	90.600	*	*	*	*	*
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.480	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	1278.686	1563.730	1722.676	2020.499	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	262.900	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	*	*	*	*	*
SERVICES	721.200	*	*	*	*	*
TOTAL NONENERGY FINAL DEMAND	1136.000	*	*	*	*	*
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	*	*	*	*	*
ENERGY INTENSIVE MANUFACTURING	362.300	*	*	*	*	*
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	61.900	*	*	*	*	*
SERVICES	935.200	*	*	*	*	*
TOTAL NONENERGY GROSS OUTPUT	2213.200	*	*	*	*	*
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	0.978	1.379	1.625	2.200	0.0
ENERGY PRICE[1]		0.802	0.681	0.636	0.845	0.0
CAPITAL (INTEREST RATE)	1.068	*	*	*	*	*
LABOR	0.977	*	*	*	*	*
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	*	*	*	*	*
NATURAL GAS	19.200	*	*	*	*	*
OIL AND NGL	19.973	*	*	*	*	*
LWR	1.052	*	*	*	*	*
LMFBR		*	*	*	*	*
OTHER (HWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		*	*	*	*	*
SOLAR HEATING AND COOLING		*	*	*	*	*
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	*	*	*	*	*
ALTERNATIVE ENERGY SYSTEMS		*	*	*	*	*
OIL AND GAS IMPORTS (QUADS)	13.719	*	*	*	*	*
TOTAL ENERGY INPUTS (QUADS)	71.076	55.400	69.400	75.400	82.700	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	*	*	*	*	*
% COAL	44.500	*	*	*	*	*
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	*	*	*	*	*
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	*	*	*	*	*
GAS ($/MCF)	0.780	*	*	*	*	*
OIL ($/BBL)	8.160	*	*	*	*	*
ELECTRICITY ($/1000 KWH)	21.220	*	*	*	*	*
TOTAL ELECTRICITY (TKWH)	1.917	*	*	*	*	*
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) 1	0.972	0.802	0.681	0.636	0.845	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL
1 ENERGY PRICE IS IN 1972 $/MILLION BTU.

MODEL: DRI-BESOM SCENARIO: BASE CASE WITH CONSTRAINTS$

YEAR:	1975 ACTUALS	1975.	1985.	1990.	2000.	2010.
MACROECONOMIC ACTIVITY (CONSTANT 1972 $)[d]						
CONSUMPTION	770.300	0.0	1110.000	1285.400	1722.400	0.0
GROSS PRIVATE DOMESTIC INVESTMENT	137.800	0.0	254.300	286.300	376.300	0.0
ENERGY	28.060	*	*	*	*	*
NONENERGY	109.740	*	*	*	*	*
GOVERNMENT EXPENDITURES	261.000	0.0	344.600	406.000	567.000	0.0
EXPORTS	90.600	0.0	19.500	9.100	5.300	0.0
IMPORTS	68.100	*	*	*	*	*
ENERGY	8.620	*	*	*	*	*
NONENERGY	59.460	*	*	*	*	*
GROSS NATIONAL PRODUCT	1191.700	0.0	1728.300	1986.700	2671.000	0.0
NONENERGY FINAL DEMAND COMPOSITION (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	104.000	0.0	198.000	220.000	267.000	0.0
ENERGY INTENSIVE MANUFACTURING	262.900	0.0	669.000	691.000	913.000	0.0
ENERGY NONINTENSIVE MANUFACTURING		*	*	*	*	*
TRANSPORTATION	49.900	0.0	46.000	51.000	64.000	0.0
SERVICES	721.200	0.0	953.000	1125.000	1557.000	0.0
TOTAL NONENERGY FINAL DEMAND	1138.000	0.0	1866.000	2087.000	2801.000	0.0
NONENERGY GROSS OUTPUT (CONSTANT 1972 $)						
AGRICULTURE,NONFUEL MINING,CONSTRUCTION	279.700	0.0	318.000	349.000	425.000	0.0
ENERGY INTENSIVE MANUFACTURING	382.300	0.0	1264.000	1461.000	1908.000	0.0
ENERGY NONINTENSIVE MANUFACTURING	534.000	*	*	*	*	*
TRANSPORTATION	81.900	0.0	125.000	143.000	187.000	0.0
SERVICES	935.200	0.0	1532.000	1784.000	2396.000	0.0
TOTAL NONENERGY GROSS OUTPUT	2213.230	0.0	3239.000	3727.000	4916.000	0.0
PRICES IN CONSTANT 1972 DOLLARS OR AS AN INDEX						
IMPLICIT GNP DEFLATOR	1.273	*	*	*	*	*
ENERGY PRICE		0.0	2.839	3.627	6.367	0.0
CAPITAL (INTEREST RATE)	1.088	0.0	2.272	2.645	3.532	0.0
LABOR	0.977	0.0	2.352	2.914	4.661	0.0
UNEMPLOYMENT RATE (%)	8.500	*	*	*	*	*
DOMESTIC ENERGY PRODUCTION BY SOURCE NET OF EXPORTS (QUADS)						
COAL	13.376	0.0	16.400	21.600	30.460	0.0
NATURAL GAS	19.200	0.0	23.030	21.400	22.410	0.0
OIL AND NGL	19.973	0.0	29.400	30.280	25.300	0.0
LWR	1.652	0.0	7.000	10.000	16.200	0.0
LMFBR		0.0	0.0	0.0	1.550	0.0
OTHER (MWR, HTGR)		*	*	*	*	*
SOLAR ELECTRIC		0.0	0.180	0.450	3.200	0.0
SOLAR HEATING AND COOLING		0.0	0.220	0.540	1.710	0.0
OTHER (HYDRO, GEOTHERMAL, SHALE)	3.159	0.0	3.700	3.900	4.000	0.0
ALTERNATIVE ENERGY SYSTEMS		0.0	0.0	0.0	1.500	0.0
OIL AND GAS IMPORTS (QUADS)	13.719	0.0	4.270	4.430	8.370	0.0
TOTAL ENERGY INPUTS (QUADS)	71.078	0.0	84.200	92.600	114.700	0.0
ELECTRICITY GENERATION BY SOURCE						
% OIL AND GAS	30.600	0.0	18.000	14.000	7.000	0.0
% COAL	44.500	0.0	45.000	48.000	45.000	0.0
% NUCLEAR	9.000	*	*	*	*	*
% OTHER	15.900	0.0	37.000	36.000	48.000	0.0
DOMESTIC PRICES (CONSTANT 1972 $)						
COAL ($/MILLION BTU)	0.630	0.0	1.265	1.289	1.344	0.0
GAS ($/MCF)	0.780	0.0	2.373	2.420	2.565	0.0
OIL ($/BBL)	8.160	0.0	14.546	15.049	17.415	0.0
ELECTRICITY ($/1000 KWH)	21.220	0.0	30.758	29.910	28.857	0.0
TOTAL ELECTRICITY (TKWH)	1.917	0.0	2.707	3.441	5.158	0.0
PRIMARY FOSSIL FUEL PRICE (1972 $/MILLION BTU) **	0.372	0.0	2.143	2.200	2.428	0.0

FOOTNOTES

* VALUES NOT REPORTED FOR THIS MODEL

** THE PRIMARY FOSSIL FUEL PRICE IS COMPUTED BASED ON FOSSIL FUEL PRICES AND QUANTITIES REPORTED BY THE MODELS. (SEE EMF-TM-77-1.1)

$ THE NONENERGY SECTOR NUMBERS REPORTED ARE THE SAME AS IN THE HUDSON-JORGENSON RUNS. THE BROOKHAVEN MODEL HAS BEEN RUN WITH THESE VALUES TO OBTAIN GREATER ENERGY SECTOR DETAIL.

< SEE THE FOOTNOTES FOR THE HUDSON-JORGENSON MODEL.

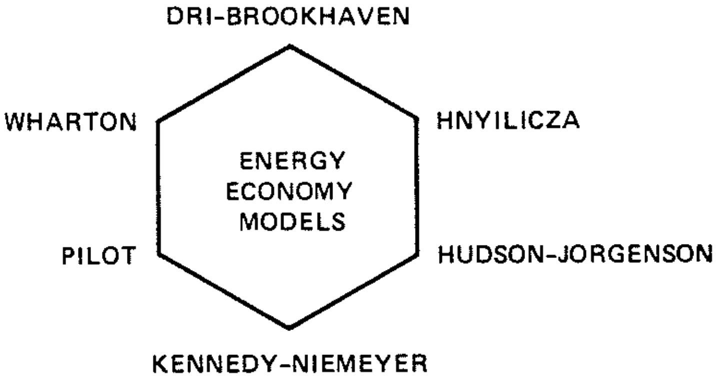
REFERENCE

[1] Darmstadter, J.; Dunkerley, J.; and Alterman, J., "How Industrial Societies Use Energy: A Comparative Analysis", Resources for the Future Report, Washington, D. C., 1977.

Appendix G

ABBREVIATED MODEL DOCUMENTATION

This appendix includes brief descriptions of the individual models participating in the EMF study. The short descriptions were prepared by the modelers or extracted from the longer documentations as available.



ABBREVIATED MODEL DOCUMENTATION

Working Paper

EMF 1.9

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Energy Modeling Forum
Institute for Energy Studies
Stanford University
Stanford, California 94305

Appendix G

ABBREVIATED MODEL DOCUMENTATION

Section 1

ABBREVIATED DESCRIPTION OF THE STANFORD PILOT MODEL

Prepared by the PILOT Modeling Group

SUMMARY DESCRIPTION OF THE MID-1976 PILOT

Our modeling activity in building the first version of the PILOT model concentrated on the supply side of the energy picture. In particular, this version of PILOT includes modeling of oil and gas exploration and extraction activities as well as the uranium extraction activities in addition to the existing and new fossil energy technologies and the nuclear fuel cycle. To provide the underlying growth setting for the economy, a dynamic input-output system is employed in which the final demand components of consumption, capital formation, imports, and exports are endogenously determined, and the government expenditures are assumed given. The labor force and its productivity growth are also assumed to be given.

The model includes a description in physical terms of the industrial processes of the economy and the demands for consumption, capacity formation, government services, and net exports. The description of the processes that provide useful energy to the economy constitutes the detailed energy submodel. This consists of technological descriptions of the raw energy extraction and the energy conversion processes as well as the energy import and export activities. Four linkages interconnect the energy sector to the rest of the economy: energy demands of the economy, bill of goods needed for energy processing and capacity expansion, total manpower available to all sectors (including energy), and a trade balance constraint which requires equating of total exports to total imports when these items are evaluated in 1967 dollars over each five year period.

The industrial sectors of the economy are represented by a 23 order input-output matrix. The sectors are grouped as follows: 5 energy sectors, 1 agriculture, 1 nonenergy mining, 5 energy intensive manufacturing, 4 energy nonintensive manufacturing, 4 services, and 3 capital formation. For computational efficiency, a modification recently was implemented that also permits construction of the model at a more aggregated 12 sector detail. Here five energy sectors are preserved but nonenergy sectors are aggregated into the following seven sectors: agriculture, mining and construction, energy intensive manufacturing, energy nonintensive manufacturing, transportation, services, and machinery and transportation equipment. Consumption is modeled in terms of consumption patterns of the average consumer. This sector does not have a fixed bill of goods; the consumption vector varies as a function of a parameter representing the total per capita consumption attained.

Capital formation needed for replacement of retired plant and equipment as well as for capacity expansion is endogenously modeled. Capacities for various processes are differentiated from one another. The capital equipment of the nonenergy sectors is depreciated exponentially whereas the energy facility capacities are assumed instead to have fixed physical service lives.

Construction lags are used to specify the time it takes to build new capacity. These construction lags may be varied individually for all 18 nonenergy sectors as well as for all energy facilities.

Exports are treated as final demand items. The imports are considered in two parts, noncompetitive and competitive. The noncompetitive imports are for those goods and services for which no domestic substitutes exist. They are treated as a part of the technology of the consuming industrial sector. On the other hand, competitive imports of goods and services for which domestic substitutes do exist are treated as activities that can augment the domestic production by a desired amount. Finally, the trade balance constraint ties together the amounts of all imports and exports. It requires that the revenues from exports be no lower than the cost of imports when these items are evaluated in 1967 dollars.

The detailed energy sector contains conventional energy technologies, such as oil refineries, coal fired power plants, etc., as well as new technologies of the future, such as coal synthetics, oil shale, plutonium recycle reactors, etc. (Figure G-1).

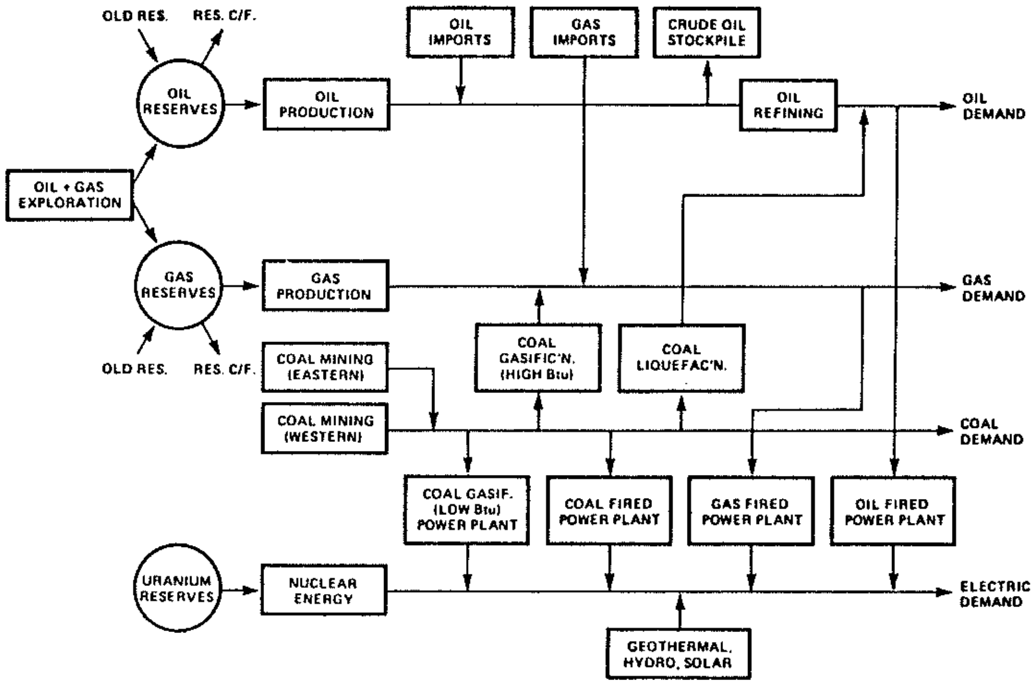

Figure G-1 The Energy Sector of PILOT

As noted earlier, the energy sector also includes a description of the exhaustion process of the three exhaustible energy resources: oil, gas, and uranium. For oil and gas, finding rate functions are used to specify the amount of oil-in-place and gas reserves to be found for a given amount of drilling effort. The level of drilling effort is endogenously determined. The advanced (and expensive) techniques of secondary and tertiary recovery also are defined in the model. For natural uranium, the increasing effort (hence increased cost) to extract it is modeled in terms of the progressively higher amounts of uranium mining and milling capacity needed due to poorer ore quality as more and more uranium is extracted. In both of the above cases, piecewise linear approximations are used to model the nonlinear functions while preserving the linearity of the constraints.

The maximand in the mid-1976 PILOT is the undiscounted sum of the gross national consumption over 40 years, subject to: a "monotonic per capita consumption" constraint, requiring that the average per capita consumption must be nondecreasing over time; an initial condition stating a lower limit on the first period consumption, and a terminal condition stating a lower limit on the amount of capital formation in the last period.

DEFICIENCIES IN THE MID-1976 PILOT

In its present form, the model includes: detailed description of the energy technologies, explicit description of the exhaustion processes for oil, gas, and uranium, the dynamics of the capital formation and the resource extraction that explicitly take into account the intertemporal tradeoffs, nonmalleable capital, variable construction lags, endogenous treatment of trade with the rest of the world, and consumption functions that were derived using a procedure that assumes equal absolute additions to income of all income groups and that describes the changing patterns of consumption with the changes in the standard of living as measured by the aggregate level of per capita consumption.

The model also contains a flexibility to experiment with the exogenously specified temporal profiles of consumer fuel mix. This feature makes it possible to examine the effects of the interfuel substitution by consumers, especially in those scenarios where initial optimization indicates wide dispersion in the shadow prices of different fuels. There also is a flexibility in the model to examine the effects of reduced energy demand resulting from the conservation and efficiency measures implemented by the consumers and the industry, either voluntarily or through legislative means.

This version of the model, however, does have some weaknesses. It does not contain explicit modeling of the substitution possibilities on the energy demand side. Thus, the possibilities of switches by the consumers and the industry from the scarce forms of fuels to more abundant forms of fuels, nonenergy materials, labor, or capital are not endogenously considered in the model. The main disadvantages here consist of the necessity of examination of the solution outputs for bottleneck reducing substitutions, and reoptimization with appropriate adjustments in the matrix coefficients. Such reoptimizations, however, could be time consuming and cumbersome.

On the energy supply side, a weakness in the model is an absence of the endogenous descriptions of the requirements for the environmental related hardware, particularly with respect to coal usage. The total coal production, therefore, is essentially exogenous in the model. Also, the 40 year planning horizon of the model is not long enough for certain decisions related to energy. Two examples worthy of mention in this regard are the decisions related to the fast breeder reactor and the central station solar technologies.

CURRENT MODEL DEVELOPMENTS

Most of the developments, of course, deal with overcoming the deficiencies just outlined.

- Coal Module--Physical Supply Curve of Delivered Coal (factors included: water, environment, changing transportation requirements)
- Longer Planning Horizon--100 Year Model with Variable Time Period Aggregation for Computational Efficiency
- Potential Interfuel and Capital Fuel Substitution Module--Incorporates Efficiency Improvements and Constraints Imposed by Existing Stocks of Utilizing Devices
- Welfare Equilibrium Variant--Comprehensive but More Aggregate Substitution Functions for Consumers and Industry
- Financial Flow Model--To Study Market Imperfections

A coal module is being prepared that takes into account the following considerations related to significant increases in the coal production: water availability constraints, environmental considerations related particularly to high sulfur coal, and shifts as well as increases in transportation requirements related to anticipated increases in the market share of western coal. While it is true that the supply curve of coal at mine mouth is relatively flat, a more meaningful supply curve is the one for delivered coal that takes into account the above considerations. For details, see [1; Appendix C].

An approach is being developed for extending the planning horizon to 100 years. The main difficulty here is computational, resulting from 20 five year periods. The staircase structure of the PILOT model with 20 steps would take a significantly higher computational time. To overcome this difficulty, a computer program has been developed and is being tested to aggregate the 20 time periods into a smaller number of time periods. A notable feature of this program is that it will allow aggregation in a form that does not require all the time periods to be of equal length. The length of any time period in the aggregation can be any desired multiple of five years. For details, see [1; Appendix H].

A major area of development deals with modeling of the substitutions on the demand side. Two approaches are being pursued here. The first one concerns process analysis based modeling of the limited area of interfuel and capital fuel substitution, the objective of which is to facilitate studies dealing with the determination of potential substitutions by consumers away from the scarce forms of energy that explicitly take into account the fact that the demand in the short run is "locked" into the existing stock of utilizing devices, and either retrofitting or replacement is required to bring forth adjustments. For details, see [1; Appendix G].

The second approach concerns modeling of a much more comprehensive set of substitutions in the consumer and industrial demand but on a highly aggregated scale. Implementation of substitutions is achieved through a hierarchy of pairwise substitutions. "Hierarchical homothetic functions" are used to mathematically express the choice making behavior and technological substitutions. This approach is described in some detail [2].

Finally, some basic research is being conducted in the area of modeling market imperfections. The key idea here is an observation that the shadow prices from linear programming are marginal prices and not reflective of market prices which may be affected in part by institutional factors. The purpose of the Financial Flow Model is to derive an additional set of dual variables which reflects a number of institutional relationships that cannot be captured in the Physical Flow Model. For details, see Avriel and Dantzig [3] and Jackson and Dantzig [1; Appendix J].

Section 2

ABBREVIATED DESCRIPTION OF THE KENNEDY-NIEMEYER MODEL

Abstracted from "Energy and Economic Growth"
Prepared by Michael Kennedy and E. Victor Niemeyer [4]

SOLUTION OF THE MODEL

A summary of the mathematical conditions for equilibrium in the model and a brief outline of the solution procedure follows.

In each year, there are 10 commodities which are in perfectly inelastic supply. These are the amounts of capital services available to each sector ($\overline{K}_i$, i = 1,...9) and total labor available ($\overline{L}$). The solution procedure finds a set of prices that has the property that the derived demands for each of these commodities equals their fixed supply. Output prices (P_i, i = 1,...9) and GNP are functions of factor prices (r_i, i = 1,...9, and w); final net demands are functions of output prices and GNP; gross demands are functions of net demands, and derived demands for capital services and labor are functions of factor prices and gross demands. As a result, derived demands for factor inputs can be reduced to functions of only factor prices in any given year. (This logic follows the outline of a competitive economy given by Arrow and Starrett [5].)

Finding the equilibrium of the model, then, reduces to finding a set of factor prices with the property that the derived demands for factor inputs equals their supply. This is essentially a problem of solving a system of 10 equations for 10 unknowns. We have developed an algorithm for finding the equilibrium factor prices.

The complete set of mathematical relations which must be satisfied by the equilibrium values of the endogenous variables is given below.

MATHEMATICAL DESCRIPTION OF THE MODEL

In each year, the exogenous variables are

L--labor supply

$\underline{\bar{K}} = (\bar{K}_i,\ i = 1,\ldots,9)$--capital stock available for use in sector i

A--a 9 x 9 matrix of intermediate input-output coefficients

$\underline{X}, \underline{M} = (X_i,\ M_i,\ i = 1,\ldots,9)$--exports and imports of the output of each sector

The endogenous variables are

$\underline{r} = (r_i,\ 1 = 1,\ldots,9)$--price of capital services to each sector

w--the wage rate, normalized at unity

$\underline{p} = (p_i,\ i = 1,\ldots,9)$--the price of output of each sector

$\underline{Q} = (Q_i,\ i = 1,\ldots,9)$--gross domestic output of each sector

$\underline{C} = (C_i,\ i = 1,\ldots,9)$--consumption of the output of each sector

$\underline{G}, \underline{I} = (G_i,\ I_i,\ i = 1,\ldots,9)$--spending by government and by investors on the output of each sector

B--a 10 x 9 matrix, partitioned as

$$\begin{bmatrix} b_L \\ \hline \begin{matrix} J_1 & & & & 0 \\ & J_2 & & & \\ 0 & & \ddots & & \\ & & & \ddots & \\ & & & & J_9 \end{matrix} \end{bmatrix}$$

where b_L is a 1 x 9 vector of direct labor coefficients

J_i, $i = 1,\ldots,9$ is the direct capital input coefficient for the ith sector

The model finds a set of endogenous variables in each year that satisfies these general equilibrium conditions:

$B = B(w, \underline{r})$--derived from production functions

$Y = wL + r'\underline{K}$--an income identity

$P = A'P + B'\binom{w}{r}$

$Q = AQ + \underline{C}(\underline{p},Y) + \underline{G}(\underline{p},Y) + \underline{I}(\underline{p},Y) + \underline{X}(\underline{p},Y) - \underline{M}(\underline{p},Y)$--supply equals demand on product side

$\binom{L}{K} = B\underline{X}$--supply equals demand on factor side

The next year's capital stocks then are computed as described above.

NUMERICAL ASSUMPTIONS

As yet, we have not attempted to estimate the parameters of this model with historical data. Instead, we have made assumptions about the values of the parameters, which are listed below. Where possible, the parameters used were adopted from the Hudson-Jorgenson model (1974) and its underlying data base (1973).

As a result, the simulations we have done are illustrative and have the purpose of indicating the qualitative features of the model. In these simulations, we simply want to see what directions the equilibrium solution is pushed when key exogenous variables, particularly those representing conditions of energy supply, are varied.

The behavior of a system such as this is so complex that analytical expressions of derivatives of endogenous variables with respect to exogenous variables are impossible to derive, so that simulation is the only effective method of learning about it at all. In addition, the numbers we have chosen are meant to represent the U.S. economy. Thus, we feel that the results have some real world relevance, although the reader must judge for himself.

Section 3

ABBREVIATED DESCRIPTION OF THE WHARTON MODEL

Abstracted from "The Structure of the Wharton Annual Energy Model"
Prepared by Lawrence R. Klein and William F. Finan [6]

INTRODUCTION

Wharton Econometric Forecasting Associates (WEFA) has an ongoing long run macroeconomic forecasting project. The main tool of this forecasting effort is the Wharton Annual Model. The distinguishing feature of this model is its fully integrated 47 industry sector input-output (I-O) table. A column input modeling algorithm allows I-O technical coefficient change to be endogenized. Coefficient movements are a result of both technical change and price induced substitution among industry inputs.

While the existing Annual Model structure allows a fine degree of industry detail to be modeled, the energy sector (especially primary energy producing industries, such as crude oil production, natural gas production, and coal mining) is not sufficiently detailed. A major objective of the energy modeling effort at WEFA has been to restructure the Annual Model to improve the energy sector detail. Increased detail has been added through two approaches. First, external to the I-O table, energy using and supplying industries have been modeled through the use of what is called "satellite models". Appending satellite models to the macromodel allows energy related industries to be modeled in detail. The second step taken to increase energy detail was to modify the I-O table of the Annual Model. The I-O table was disaggregated to display important energy using and supplying sectors. Work also was initiated to respecify the column input modeling algorithm to improve the model's behavior with respect to the problem of long run interfuel substitution.

INTRODUCTION OF I-O INTO THE MACROMODEL STRUCTURE

Table G-1 shows the sectoring in detail. Major energy consuming industries which are particularly important for energy policy studies of interfuel substitution

Table G-1

WHARTON ANNUAL ENERGY MODEL SECTORING[†]

SECTOR NUMBER	
1	Farm, Agricultural Services, Forestry, and Fisheries
2	Metal Mining
3	Coal Mining
4	Crude Petroleum and Natural Gas Liquids[*]
5	Natural Gas[*]
6	Nonmetallic Minerals Mining
7	New Construction, Nonfarm residential
8	New Construction, Nonresidential
9	New Construction, Other
10	New Construction, Utilities
11	Food and Beverages
12	Tobacco
13	Textile Mill Products
14	Apparel and Related Products
15	Paper and Allied Products
16	Printing and Publishing
17	Industrial Organic and Inorganic Chemicals
18	Chemicals, Other
19	Petroleum Refining and Related Industries
20	Rubber and Miscellaneous Plastic Products
21	Leather and Leather Products
22	Lumber and Wood Products
23	Furniture and Fixtures
24	Cement
25	Stone, Clay, and Glass Products, Other
26	Iron and Steel
27	Primary Aluminum
28	Primary Nonferrous Metal (excluding Aluminum)
29	Fabricated Metal Products
30	Nonelectrical Machinery
31	Electrical Machinery
32	Ordnance, Other Transportation Equipment
33	Motor Vehicles and Parts
34	Instruments, Related Products, and Miscellaneous Manufacturing
35	Railroads
36	Local, Suburban, Interurban Highway Passenger Transportation
37	Motor Freight Transportation and Warehousing
38	Water Transportation
39	Air Transportation
40	Pipeline Transportation
41	Transportation Services

[†] Underlining denotes changes from existing macromodel table.

[*] Exist only as separate sectors along row

WHARTON ANNUAL ENERGY MODEL SECTORING (Continued)

SECTOR NUMBER		
42		Communication
43		Electric Utilities
44		Gas Utilities
45		Water and Sanitary Services
46		Wholesale Trade
47		Retail Trade
48		Finance and Insurance
49		Real Estate
50		Services
	(51)	Eliminated R and D †
51	(52)	Federal Electric Utilities
52	(53)	Other Federal Enterprises
53	(54)	Local Government Passenger Transit
54	(55)	State and Local Electric Utilities
55	(56)	Other State and Local Government Enterprises
56	(57)	Imports
	(58)	Business Travel and Entertainment †
	(59)	Office Supplies †
	(60)	Scrap, Used and Secondhand Goods †
57	(61)	Government Industry
58	(62)	Rest of World
59	(63)	Inventory Valuation Adjustment

FINAL DEMAND

A. Consumption

60	(1)	Autos
61	(2)	Furniture and Fixtures
62	(3)	Other Durables
63	(4)	Food and Beverages
64	(5)	Clothing and Shoes
65	(6)	Gasoline and Oil
66	(7)	Other Nondurables, Fuel Oil
67	(8)	Other Nondurables, except Fuel Oil
68	(9)	Housing Services
69	(10)	Household Operating Services, Electricity
70	(11)	Household Operating Services, Gas
71	(12)	Household Operating Services, Other
72	(13)	Transportation Services
73	(14)	Other Services

B. Fixed Investment

74	(1)	Farm
75	(2)	Ore and Nonmetallic Minerals Mining
76	(3)	Coal Mining
77	(4)	Crude Petroleum and Gas Mining
78	(5)	Primary Iron and Steel
79	(6)	Aluminum
80	(7)	Other Primary Nonferrous

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† Eliminated from final table

WHARTON ANNUAL ENERGY MODEL SECTORING (Continued)

SECTOR NUMBER		
81	(8)	Electrical Machinery
82	(9)	Nonelectrical Machinery
83	(10)	Motor Vehicles
84	(11)	Aircraft, Ordnance, Other Transportation Equipment
85	(12)	Cement
86	(13)	Other Stone, Clay, and Glass
87	(14)	Fabricated Metals
88	(15)	Lumber
89	(16)	Furniture
90	(17)	Instruments and Miscellaneous Manufacturing
91	(18)	Food and Beverage
92	(19)	Textiles
93	(20)	Paper
94	(21)	Chemicals
95	(22)	Petroleum Refining
96	(23)	Rubber
97	(24)	Apparel
98	(25)	Leather
99	(26)	Printing
100	(27)	Transportation
101	(28)	Electric Utilities
102	(29)	Gas, Water Utilities
103	(30)	Communication
104	(31)	Commercial, Other
105	(32)	Tobacco

C. Trade

106	(1)	Exports, 0 + 1 [†]
107	(2)	Exports, 2 + 4
108	(3)	Exports, 5 - 9
109	(4)	Exports, Coal, 3
110	(5)	Exports, Other Fuel, 3
111	(6)	Exports, Services
112	(7)	Imports, 0 + 1
113	(8)	Imports, 2 + 4
114	(9)	Imports, 5 - 9
115	(10)	Imports, Crude Oil, 3
116	(11)	Imports, Residual Fuel Oil, 3
117	(12)	Imports, Natural Gas, 3
118	(13)	Imports, Other Fuels, 3
119	(14)	Imports, Services

D. Inventories

120		Inventories *

[†] SITC Code

*Inventories are exogenous.

WHARTON ANNUAL ENERGY MODEL SECTORING (Continued)

SECTOR NUMBER

E. Government

121	Federal National Defense
122	Federal Nondefense, Other
123	State and Local Education
124	State and Local Health and Welfare
125	State and Local Safety
126	State and Local, Other

have been disaggregated in the I-O table. The number of final demand categories also was expanded.

At a general level, the energy supplying sectors in the I-O matrix can be grouped into two categories: primary energy producing industries (crude oil production, natural gas production, and coal mining) and secondary energy producing industries (refining, electricity generation, and nuclear fuel processing). WEFA obtained the MacAvoy-Pindyck Natural Gas and Petroleum Exploration Model to model domestic natural gas and petroleum supply. This model, combined with Wharton's Coal Model, provides a detailed complete presentation of the domestic primary energy producing industries. Coal, natural gas, and crude petroleum output exist in the disaggregated input-output table as separate sectors. Thus, the primary energy supply sectors are fully integrated into the I-O table. The secondary energy producing industries are not modeled at a similar level of detail in the present version of the model. These sectors are included in the macromodel I-O table and are handled with the existing macromodel structure. Petroleum refining, electric power generation, and natural gas distribution exist as separate sectors. Future work will expand the detail of the secondary sectors.

Important energy using sectors are included in the I-O table at a highly disaggregated level. For example, cement, iron and steel, and primary aluminum exist as separate sectors. Work also is under way to model key energy using sectors with satellite models and/or process models.

ALTERNATIVE APPROACHES TO MODELING COLUMN INPUTS

In the present version of the macromodel, changes in column inputs are modeled by an approach developed by Dr. Ross Preston [7]. Preston has shown that if industries combine least cost intermediate inputs subject to a CES production constraint with given outputs, a linear formulation of the intermediate input demand function can be derived and estimated.

While Preston's approach to modeling column changes was a major improvement over earlier techniques, it was not felt to be completely satisfactory with respect to modeling changes in the composition of energy inputs. For example, a common substitution elasticity is applied to all inputs. Clearly this is an extreme assumption above. One solution is to group column inputs into basic layers with differing elasticities within and between layers. Wharton also is investigating two other approaches to estimate substitution parameters between pairs of column inputs: the use of satellite models, and statistical cost functions. These approaches will be discussed now.

Satellite Models

A satellite model is "one that studies detailed interrelationships of an industrial sector or significant parts of it separate from the macroeconomic system". Satellite systems are constructed to model industry structure, particularly with respect to energy consumption, in a highly detailed manner. This micromodeling approach allows adjustments of the composition of industry inputs to relative price movements, shifts in material availability, or technological change. Since the satellite systems are integrated with the macrosystem, compositional shifts determined in the satellite system affect the main macromodel solution.

Modeling Column Input Change with Statistical Cost Function

Professor James M. Griffin, University of Pennsylvania, has proposed a new procedure to model changes in I-O technical coefficients which combines industry process models with statistical cost function estimation [8]. Process models of various industries tend to be of such a large size they cannot be introduced directly in the macromodel despite their explicit description of the technology and ability to elicit the cost minimizing inputs corresponding input-output coefficient for that input. The statistical cost function is estimated from "pseudo data" generated by the process model. "Pseudo data" are generated by solving the industry process model for alternative vectors of relative input prices. Each solution yields the corresponding cost minimizing input levels and total costs. This information becomes the observations in the pseudo data sample which then are used to estimate a statistical cost function. In essence, the statistical cost function serves as a type of reduced form description of the technological structure. A dynamic adjustment process, such as in the layered Hickman-Lau, then is used to model the movement from one long run cost function to another [9].

CONCLUSION

The Wharton energy modeling approach is to integrate highly detailed satellite systems with a disaggregated I-O table. Solution of the linked system allows the impact of alternative energy scenarios to modify the composition of industry fuel inputs, and in turn, feed through to the I-O table to the remainder of the model.

Section 4

ABBREVIATED DESCRIPTION OF THE HUDSON-JORGENSON MODEL (DRI LITM)

Provided by Robert C. Dullien

The DRI Long-term Interindustry Transactions Model (LITM) has been created from the Hudson-Jorgenson Macroeconomic and Interindustry Models for the United States economy [10]. These models have been integrated through a method that allows the rapid inclusion of further submodels as well as the more efficient use of the system for policy analysis purposes. The Interindustry part of the combined model has been revised through the inclusion of production functions for nuclear, hydroelectric, geothermal, solar (utility), and direct solar energy production as well as shale oil production and coal liquefaction and gasification.

The Macroeconomic Model (MM) provides the general characteristics of the economic environment. It consists of behavioral equations fitted with parameters using data for the 1947-1973 period and also of accounting identities. It projects the amount and price of consumption, investment and capital and labor service inputs on a yearly basis. The demand for goods and services by government, the amount of exports net of imports, the supply of labor, the percent of labor unemployed, and the inflation rate for the economy as a whole are exogenous to the MM.

The Interindustry Model (IM), in the LITM framework, provides a means of disaggregating the Macroeconomic Model's projections to a level which is more informative, yet manageable. The economy is divided as shown in Table G-2. Of the 14 producing sectors, 10 relate directly to energy production. Three crude energy carrier extraction processes are modeled and seven energy refining processes.

The two models can be combined in two different ways due to the existence of two different sets of production functions. In Integration Mode 1, the Macroeconomic Model's production function dominates. In this mode, the Macroeconomic Model fully determines the growth path of aggregate inputs and outputs for the economy.

Table G-2

PRODUCING SECTORS OF THE DATA RESOURCES, INC. LONG-TERM INTERINDUSTRY TRANSACTIONS MODEL

SECTOR NUMBER	
	MAJOR PRODUCING SECTORS:
1	Agriculture and Nonfuel Mining
2	Manufacturing, excluding Petroleum Refining
3	Transportation
4	Communication, Trade, and Services
5	Coal
6	Crude Petroleum
7	Crude Natural Gas
8	Refined Petroleum and Substitutes
9	Electricity
10	Refined Natural Gas and Substitutes
	HYDROELECTRIC, NUCLEAR, AND UNCONVENTIONAL ENERGY PRODUCTION SECTORS:
11	Nuclear Energy
12	Hydroelectric
13	Geothermal
14	Solar Electric
15	Shale Oil
16	Coal Liquefaction
17	Coal Gasification
18	Solar Direct

The Interindustry Model then is calibrated to agree with the Macroeconomic Model's aggregate results. This type of integration is useful for establishing long term projections from scratch and studying the effects of certain Federal tax or other macroeconomic policies.

In Integration Mode 2, the production functions endogenously determined in the Interindustry Model dominate. The Macroeconomic Model is reduced to keeping track of the supply of labor and capital and the determination of consumption and investment demand. This mode allows the analysis of the effects of policies or assumptions that relate to one or more sectors of the IM.

The two models are integrated using a framework which allows the user to select any of a number of available equations and variables for inclusion in the simultaneous equation system. If one sees the need to endogenize a formerly exogenous parameter, one may do so by adding an equation to the already existing system. Or one may add a whole set of equations that, in fact, comprise a whole other model. The effect of the existence of this framework is that models can be integrated with ease and that additional equality constraints can be added without doing any computer programming. It thus makes the use of the LITM more efficient for policy analysis purposes.

Section 5

ABBREVIATED DESCRIPTION OF THE HNYILICZA MODEL

Abstracted from
"A Long-Term Macroeconomic Energy Model: An Overview"
by Esteban Hnyilicza [11]

Our primary objective in the development of our macroeconomic model has been the formulation of an integrated and consistent framework of analysis that would relate the market mechanisms for energy products, nonenergy products, and primary factors of production to the fundamental process underlying the determination of economic growth: the link between current capital formation and future production.

The underlying theoretical basis for our macroeconomic energy model is the neoclassical theory of general equilibrium. There are three basic constituents of the general equilibrium problem:

- Producer Behavior. Given some specification of technologically feasible combinations of inputs and outputs, producers attempt to acquire factor services and produce goods in such a way as to maximize their flow of profit.
- Consumer Behavior. Given some representation of consumer preferences, households attempt to offer factor services and purchase goods in such a way as to attain a maximum level of utility flow.
- Market Adjustment Process. Given the demand and supply functions resulting from the characterization of producer and consumer behavior, market forces determine an adjustment process toward a set of prices for goods and factor services that clear all goods and factor markets.

Our macroeconomic model has been formulated within this basic structure, incorporating fully endogenous treatment of the production and household sectors. The role of each individual decision unit in the overall system can be established in a straightforward way. Households acting as price takers develop decisions attempting to arrive at preferred positions subject to expenditure constraints and given price data; producers acting as price takers develop decisions attempting to achieve maximum profit subject to technological constraints and given price data. Analysis of these decisions yields results describing the manner in which individual decisions are affected by changes in price data taken as given. Processes of market adjustment then alter prices until the foregoing decisions are mutually consistent and markets clear.

The other two major components of the model are the government and foreign sectors. The government sector has its revenue generated by the tax structure and the tax bases but its expenditure is largely exogenous. Demand for imports is generated as part of the system of derived factor demands in the production sector but the rest of the foreign trade sector is exogenous to the model.

The structure of production in our model incorporates two production sectors corresponding to energy and nonenergy products, respectively. The model includes five markets for products, two markets for capital services, and one market for labor services. The products are supplied by the energy and nonenergy sectors and used by all sectors; factors are supplied by the household sector and used by the two production sectors. The rate of capital accumulation and the rate of increase of wealth also are determined within the model and, together with the rate of technological progress, establish the dynamic evolution of the system. Identities that relate the income and expenditure flows across the various product categories and balance equations that summarize the conditions for market equilibrium complete the structure of the model.

The formulation of our model falls within the tradition of *general equilibrium* models because we assume that the supply and demand schedules for each good and service determine all prices and quantities transacted within a simultaneous process of market equilibration. Our formulation is *neoclassical* because we postulate that the behavioral characteristics of the basic decision units can be described in terms of maximizing behavior in the presence of appropriate constraints.

Section 6

ABBREVIATED DESCRIPTION OF THE DRI-BROOKHAVEN MODEL

Abstracted from "A Combined Linear Programming and Econometric
Systems Analysis of the Relation Between Energy, Growth, and the Economy"
Prepared by David J. Behling, Jr. and Robert C. Dullien [12]

INTEGRATION SCHEME BETWEEN BNL AND DRI MODELS

First, the flows from the DRI Combined Model to the BNL Combined Model will be described. The DRI Model is used to estimate:

- aggregate final demands for insertion into the BNL I-O Model (final demand disaggregates are based on BNL forecasts [13]);
- an aggregate interindustry input-output flow matrix, which is used to estimate aggregate input-output coefficients in the BNL Input-Output Model (disaggregates are based on BNL forecasts [13]);
- nonenergy prices, which are used to estimate the nonenergy cost components of energy conversion processes, for insertion in the objective function of the BNL LP Model;
- energy demand price elasticities, (obtained by simulation of the combined DRI Model) which are used to estimate changes in functional energy requirements in the BNL I-O Model.

The integration procedure incorporates the reverse flows from the BNL to the DRI models, as follows:

- DRI annual energy production, export and import rates are controlled to BNL estimated values.
- The BNL estimated fuel mix specification for the electric utility sector is inserted in the DRI Interindustry Model.
- The DRI aggregate capital and labor requirements are adjusted for BNL determined incremental capital and labor requirements associated with new energy technologies.
- The DRI energy prices are adjusted for BNL estimated energy scarcity values (shadow prices).

The general effect of these linkage relationships is to constrain the general equilibrium solution values to energy values determined by the BNL Combined Model.

The BNL Model, in turn, is driven by DRI estimated aggregates along with the DRI pattern of energy demand, overridden in some cases by engineering based forecasts of new energy technologies. (For example, consumer demand for gasoline in the BNL I-O Model is based on DRI estimated income and price elasticities, adjusted in some cases for the possible introduction of electric cars, and/or FEA guidelines for automobile fuel efficiency.)

SOLUTION PROCEDURES FOR INTEGRATED MODEL SCHEMES

The general research program to integrate the BNL and DRI Models is a two-fold policy and theoretical research effort. Existing models and integration procedures are being used for policy analysis, while at the same time model linkage equations, data definition consistency checks, and solution procedures for future policy analysis are being developed. For current policy applications to date, only the quantity structure of all the models have been integrated, and even with respect to quantities, the iterative solution procedures which have been utilized have not been iterated to full convergence.

The current state of the model integration effort is described in detail in [14]. In this effort, complete consistency of final demand estimates and energy quantities were obtained, but some discrepancies between models in energy allocation by sectors remained.

For future policy analysis, Dale Jorgenson and Ed Hudson of DRI have developed a scheme to fully integrate both the pricing and output structures of all models. The general nature of this integration scheme will be published in subsequent papers. Preliminary testing of this procedure has been programmed and convergent solutions were reached. However, the following two general problems remain. First, the BNL data set is not fully consistent in a definitional sense with that of the DRI Model due to such problems as inconsistent dollar to Btu conversion factors, and differing treatments of secondary product flows. Second, the BNL LP Model generates step functions relating shadow prices to energy quantities, while the DRI Combined Model incorporates only continuous functions. As a result, energy price feedback relations from the BNL to the DRI Model generate either very large or zero changes in the DRI Model solutions. Additional work to smooth out the LP generated step functions is thus required.

In addition, David Behling is developing an independent integration scheme which utilizes energy price elasticity data specified with respect to the functional use of energy (space heating, water heating, etc.) as well as with respect to type of energy form (oil, electricity, etc.) and purchasing industry (steel, aluminum, paper, etc.). This scheme is still in the development stage.

While the nature of the eventual linkage and computer relations between the DRI Combined Model and the BNL Combined Model still is under investigation, much work has been done in aligning the DRI Combined Model for BNL estimated quantity values. The mechanism which performs the alignment of endogenous results with exogenous target values for the DRI models is a generalized version of the linear Newton's method algorithm. There is significant flexibility in the selection of variables for this scheme. Available state and control variables are catalogued in the computer program manual. The user can select the set of state variables which will be adjusted through a user-selected set of control variables until they match a user-specified set of target values. The algorithm is highly efficient. The user is able to keep the amount of computation to the bare minimum by specifying, as input, which off-diagonal elements of the Jacobian need to be computed.

The alignment of the BNL Combined Model for DRI determined magnitudes involves only the adjustment of parameters exogenous to the BNL Combined Model. Currently this adjustment is done manually.

USE OF INTEGRATED SCHEME IN POLICY ANALYSIS TO DATE

This model integration scheme has been used to estimate the income, output, employment, price, and oil and gas import displacement effects of alternative combinations of energy research and development and energy taxation policies. The results of this study are contained in [14]. Currently the same preliminary version of the integrated scheme also is being used to generate forecasts of energy production and consumption levels from 1985 to 2000, using the FEA \$13 per imported barrel of oil reference scenario as the 1985 starting point [15]. Parametric solutions also are being estimated on the basis of alternative policy specifications as to imported oil prices (and/or tariffs or quotas) and levels and mixes of new energy technology availabilities.

FUTURE ANTICIPATED RESEARCH EFFORTS

Besides reconciling the data bases of the various BNL and DRI Models and developing and implementing fully consistent and efficient solution schemes to integrate both the price and output structures of the individual models, several additional research efforts are inticipated. At present, all models included in the integration scheme are defined with respect to national averages. However, an interregional version of the BNL linear programming allocation model currently is being developed at BNL. When completed, this interregional model will be incorporated into the integration scheme, permitting regional estimates of energy production, transportation, and consumption activities.

Currently several energy sector supply models are being tied to the DRI Interindustry Model [16]. These supply models also will be used to generate price, supply relationships which, in turn, will be tied to the Brookhaven LP Model. At present, domestic energy supply amounts are specified either completely exogenously or are determined on the basis of exogenously specified supply price elasticities. Prices, in turn, are estimated either on the basis of expected average costs of production plus endogenously determined incremental scarcity values or on the basis of exogenously determined import prices. More explicit treatment of supply relationships will permit more detailed analysis of government policies affecting supply relationships (e.g., the effect of energy profit taxes and expected drilling or mining rates).

A dynamic version of the Brookhaven LP Model also is being developed by William Marcuse and Lawrence Bodin of BNL [17]. When completed, this model will be used to estimate optimal scarcity values of domestic energy resources and capacities over time. Scarcity values estimated in static versions of the LP Model then will be checked against corresponding scarcity values obtained in the dynamic model so as to incorporate into the integration framework the influence of possible future energy resource scarcities on present resource prices.

Research on estimating possible future microrelationships between energy prices, energy research and development expenditures on energy utilizing processes, and energy consumption levels also is being initiated at BNL. At present, only macrorelationships between industrial output, energy consumption, and energy prices are incorporated in the integrated framework along with the interfuel substitution possibilities for meeting functional energy requirements.

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