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# Integrated Energy System Modeling and Policy Analysis: Description of an I.I.A.S.A. Research Program

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# INTEGRATED ENERGY SYSTEM MODELLING AND POLICY ANALYSIS: A DESCRIPTION OF AN IIASA RESEARCH PROGRAM

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# Integrated Energy System Modelling and Policy Analysis

## A Description of an IIASA Research Program

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# Integrated Energy System Modelling and Policy Analysis

## A Description of an IIASA Research Program

### I. Introduction

This working paper describes an IIASA research program which was initiated early in 1975. The research project not only cuts across a number of disciplines and groups at IIASA, but is also conducted in close cooperation with external research institutes in IIASA member countries. This first working paper lays out a proposed initial research structure and interinstitutional framework as a basis for the work of the coming months. It is the result of a synthesis of my initial conception of this research and a distillation of the input and suggestions from several individuals at IIASA. Although the research is already well underway within the general framework described here, the program structure is meant to be flexible and dynamic. As the collaborating institutions play an increasing role in the coming months, it is anticipated that program changes will evolve, particularly because of the innovative nature of both the research content and the interinstitutional format.

A. Background of the Research

Energy Planning and Policy Analysis

Energy has achieved a new and prominent status in our societal planning processes -- it is becoming an explicit rather than implicit variable. For example, in the United States, this phenomenon has occurred at almost all levels of decision making, ranging from the home-owner, developing his preference for a specific air conditioner type or model, to national and international discussions over mechanisms to combat inflation through reductions of petroleum demands. Planners in the public and private sectors of agriculture, architecture, urban and transportation systems are beginning to treat energy much more explicitly. Because of the complex manner in which energy is intertwined with virtually all of the characteristics of an industrialized society, this recognition of the importance of energy is having a strong influence in virtually all technological, economic and environmental decision making bodies.

In contrast to North America, energy planning in many European countries has for many years played a much more explicit role in the public sector. In part this is due to the fact that energy has long been considered a scarce resource in many of these countries.

Energy Embedding at the Regional Level

In several industrialized countries, this greatly-intensified concern with energy planning has emerged at all levels of government. The grass roots public concern about energy and its effect on day-to-day existence has stimulated much greater action on the part of local, state, and regional governments. It is clear that national energy policy formation must take subnational and local characteristics into account. One major reason for this phenomenon originates with the diverse ways in which each region within a nation or a part of the world depends upon energy. For example, a primarily-consuming region, which neither extracts nor processes primary fuel, in general employs a distinct set of objectives and values in formulating energy policies; these are in most cases quite different from those in an energy-producing region. In a similar manner, the considerations differ between industry- and tourism-oriented regions, between agricultural and urban regions, etc. The maze of interdependencies between energy and the total human enterprise in each region binds its energy policy objectives quite tightly to the natural and man-made characteristics of that region. The recognition of this bond has made apparent the great need for an improved understanding of energy systems and their embedding in society at the regional level.

The major world or global models provide very little regional or even national energy policy guidance. Even the Pestel-Mesarovic world model (1) although treating energy as an explicit variable in a world divided into ten regions, provides only limited assistance to regional energy decision makers.

## Alternative Energy Futures

Many national and global energy studies now underway are exploring the consequences of a spectrum of supply scenarios, e.g. the nuclear fission, fusion, and solar options. In addition various studies are underway to provide information on future energy demands. However, conspicuously missing from the current array of energy research is a major class of scenarios which integrates demand and supply scenarios and their embedding in a specific regional environment.

It has been convincingly demonstrated many times (e.g. 2,3) that over almost any conceivable time period the limitation on man's use of energy will not be due to the amount of energy stored in the earth or the sea or in space. That is, the potential energies from breeder reactors, fusion, and the sun are enormous. Rather, the limit will most probably originate from man's inability to convert this energy into a useful form at acceptable costs, or from his unwillingness to accept some of the consequences which may accompany the conversion of these sources of energy into useful work. These consequences may be in the form of a broad spectrum of environmental effects (with the term environment used here in a very general sense) or in the form of unacceptable risks - many of which will be poorly understood, vaguely perceived, or even hypothetical. Some of these consequences may be primarily global in nature, but a majority of them, although having certain universal characteristics, derive a specific meaning only when related to a given region or human environment.

A second or perhaps even more controversial aspect of man's future energy systems is their relationship to economic growth and well being. Are there global or regional limits to our energy systems? If there are limits, how can these systems be designed so as to maximize human welfare? What would be the economic consequences of such limits for the less energy-intensive countries or regions; for the less-developed regions and countries? Will these regions need to consider alternative energy systems, e.g. solar or low-energy technologies? These questions of energy resource management cannot be answered from a purely global perspective.

B. Integrated Energy System Modelling and Policy Analysis - An Applied Research Theme

In simplest terms, the research project described here is the development and the comparison of a set of case studies of regional energy systems. Within this context, "regional" is rather ill-defined, and really means an energy system of limited size such that one can examine its characteristics in a reasonably detailed way so as to provide a degree of disaggregation sufficient to allow significant policy analysis. In the case of the Wisconsin regional study, a prototype energy system for this research project, the region was the State of Wisconsin (4). In the case of a smaller nation, the region may be the entire country.

The primary purposes of the study are at least three-fold:

(1) To identify existing patterns of regional energy use and supply at appropriate levels of disaggregation.

(2) To compare alternative methodologies for regional energy forecasting, planning, and policy development.

(3) To use the above methodologies to examine alternate energy policy strategies for each of the regions, to explore their implications from various perspectives using sets of indicators related to environmental impacts, energy use efficiency, etc., and to evaluate the adequacy of the alternative methodologies as policy tools.

Out of these above three items should evolve improved methodologies for energy systems research and policy analysis. The comparative method, intersecting the different disciplines and nations which would be involved in this project, should serve as a powerful tool to the mutual benefit to the participating nations as well as to other countries facing similar energy problems. It could also serve as a prototype for similar studies on other resources such as materials, water, air, i.e. as a vehicle for development of an approach for improved resource management.

## II. The Research Program

### A. The Case Study Approach

Case studies have proven to be a powerful tool for the focusing of research at IIASA, particularly because of the applied methodology and the conceptual developments which have been emerging from such studies. The unusual nature of the IIASA institutional structure, research atmosphere, and staff composition make it imperative to very carefully select these applied problems. Several obvious criteria present themselves as a basis for the selection. Among the more prominent are:

(1) The case studies must lie within a set of applied problems from a general universal class.

(2) Each should be reasonably defined with a good data base.

(3) There should be an identifiable user for the output of the study, ideally policy as well as scientific clients.

(4) Each study should have enough innovative possibilities to extend certain fundamental methodological and conceptual issues.

(5) The study should provide an opportunity for a strong interrelation and rich interaction among several disciplines and groups at IIASA.

(6) The study must be of a scope and size that it can yield meaningful results in a reasonable time period. Within the current IIASA personnel framework, this is of the order of one year.

(7) The study would ideally build upon the work of already existing projects external to IIASA.

Each of the above critera has been considered during the design phase of the project described in this paper. It is believed that the project as described below goes a long way towards satisfying most if not all of these criteria.

B. <u>General Research Format</u>

A small team of IIASA scientists, cutting across several existing Research Groups, has been responsible for the initial structure of the research project. This core group is developing a working relationship with energy research projects in several IIASA member countries. The three research groups which are collaborating in the first phase of the IIASA Research Program are:

(1) The Energy Systems and Policy Research Group of the Institute for Environmental Studies, University of Wisconsin - Madison, U.S.A.

(2) Institut für Energetik, Leipzig, German Democratic Republic.

(3) Institut Economique et Juridique de l'Energie at the University of Grenoble, Grenoble, France.

Discussions for later participation are also underway with two additional research institutes in other IIASA member countries.

Each of the collaborating institutions was chosen because it has an active research program which studies energy systems from a broad resource management perspective. Equally important in the choice of the collaborating institutions is the greatly different planning and policy framework in the respective countries.

The overall interaction between IIASA and the collaborating institutions is shown in Figure 1. The core IIASA staff will work closely with each collaborating institute, and members of each of these will spend some time at IIASA. As indicated in

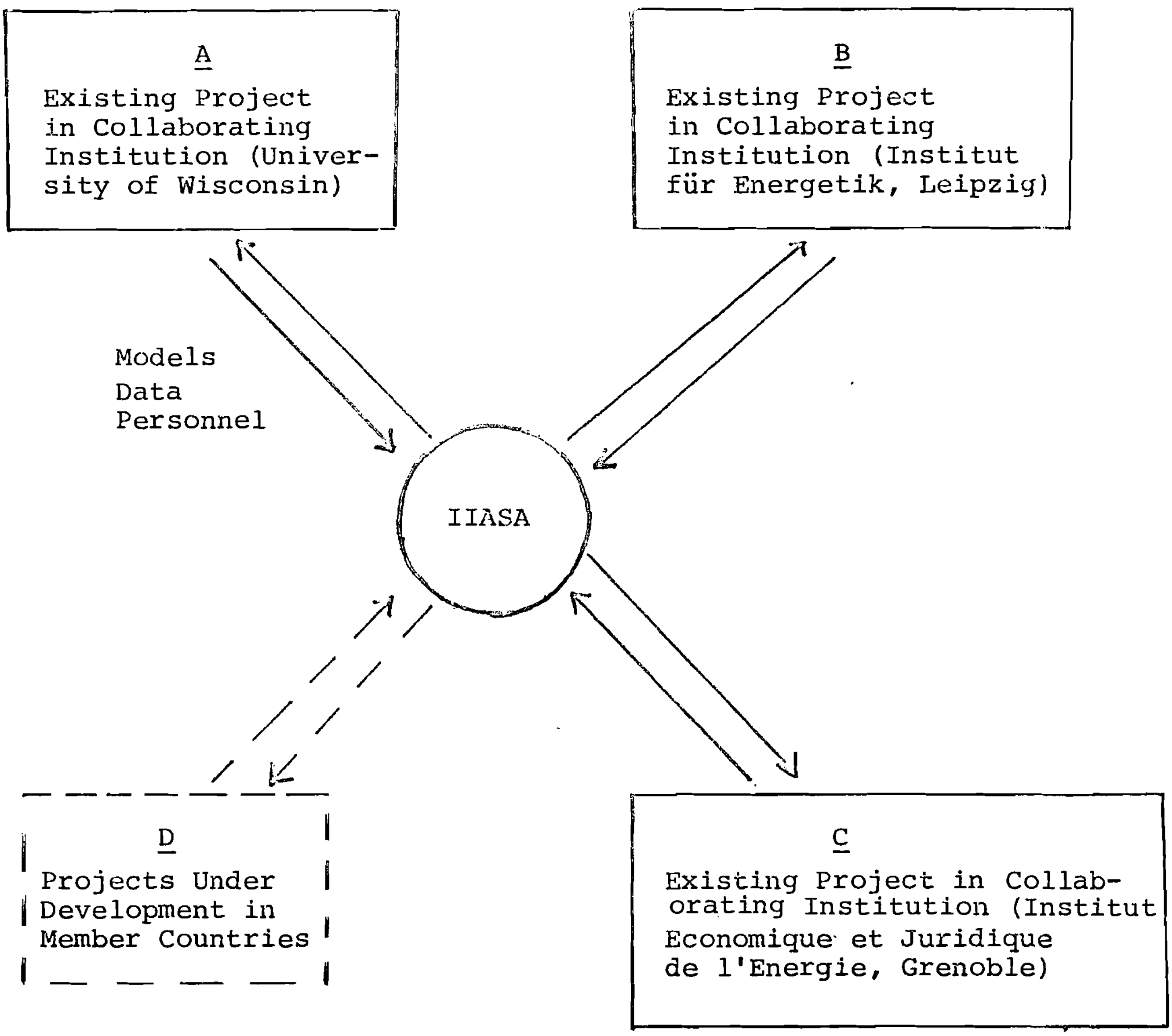


Figure 1 Interinstitutional Relationships within the Integrated Energy System Project

Figure 1, there will be an interinstitutional flow of models, data, and personnel, with the latter being exchanged either on a very short-term basis or in some cases for a longer period of time. For example, personnel from one of the collaborating projects may spend some weeks at IIASA. As shown in the dotted square, planning for a followup phase is already underway, with existing energy projects in other member countries preparing for participation.

Emphasis will be given to comparison as a method for illumination of the salient characteristics and differences among the regional energy modelling and policy analysis methodologies. The comparisons will be achieved through a research program which includes the research stages shown schematically in Figure 2. These are discussed below in more detail.

(1) Communication

One of the keys to this research program is the establishment of communication between already existing research projects. It is important that the research not be diluted through the inclusion of too many research institutes -- although the number could be expanded as the research continues if it appears desireable. Effective communication has already been established between the initial three collaboration research groups. These three integrated energy research projects will form key components in the study.

As the research structure evolves and we gain some experience with handling comparative questions of data, models, policy evaluations etc., periodic reports will be issued to

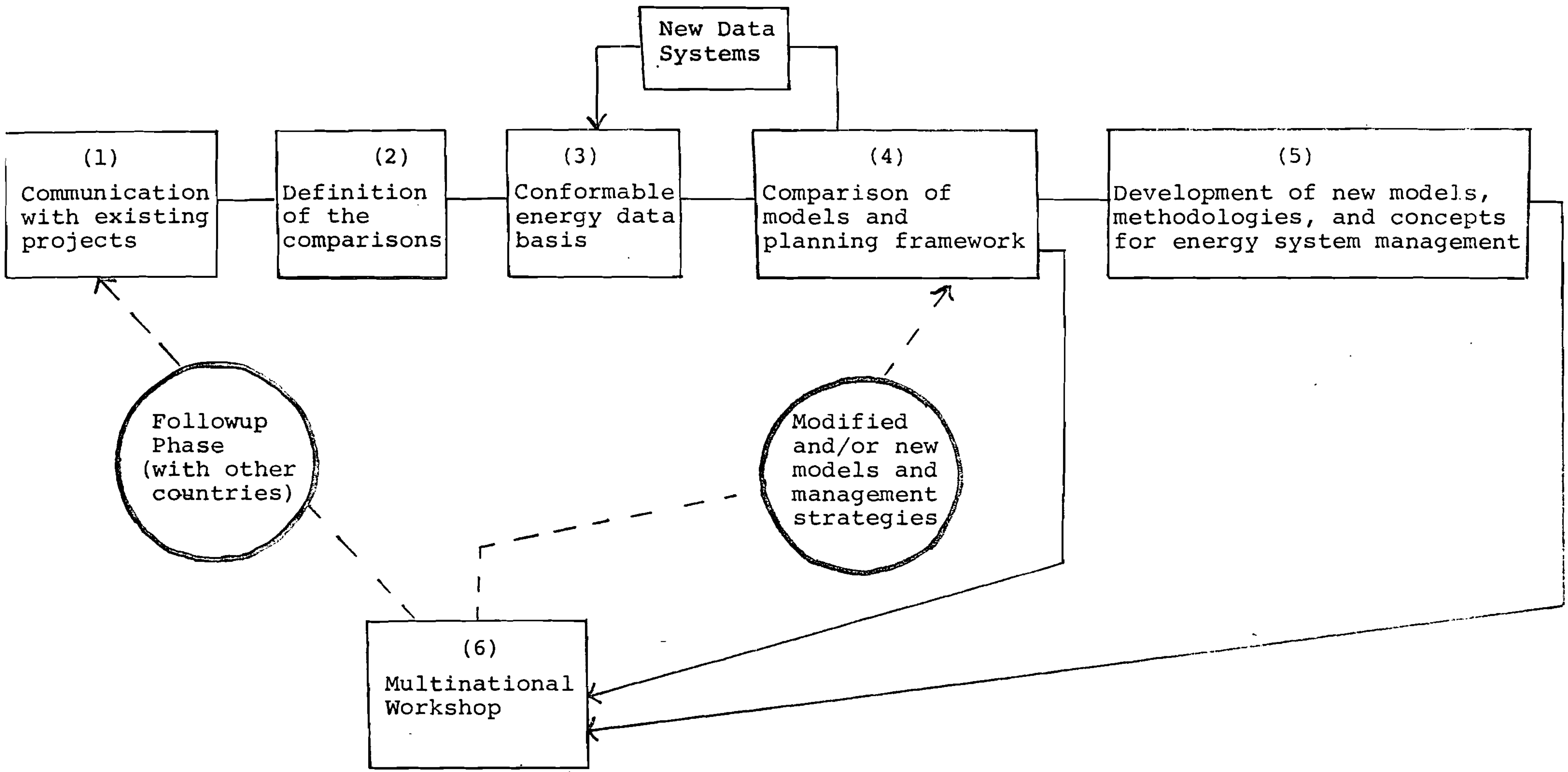


Figure 2 Stages of the Integrated Energy System Research Program

provide a basis for the development of a Followup Phase to the project with another set of countries or regions having greatly different energy system characteristics.

(2) Definition of the Energy System Comparisons

This work will define those areas in the energy systems which will be modelled, compared, etc. This is an important stage of the research since it will structure much of the activity in the coming months. Included in the definitions are the general questions:

Which models will be analyzed and to what degree? Demand? Supply? Environment?

How much effort will be devoted to building new models or modifying existing models?

What data will be required for meaningful analysis of the models and for a comparative policy analysis?

What policy questions are appropriate for evaluation of the models?

Some of the above questions have already been answered whereas others will be discussed at small working sessions in April and May of 1975 with participation by the IIASA core group and each of the collaborating institutions.

Section III of this report describes a proposed structure of these research components, including areas of focus, data requirements, suggested application and development models, etc. This proposed structure will be discussed at the April and May working sessions.

(3) Conformable Energy Data Basis

In order to understand and evaluate the utility of the various methodologies for forecasting planning and policy analysis, it will be necessary to work with consistent sets of data. The development of consistent sets will require effort very early in the research program. Examples of these sets would be time series of energy demand in each of the sectors, energy prices as function of time, etc. This is discussed further in Section III.

(4) Comparison of Models

After the areas of comparison are defined, e.g. supply, demand, environmental impacts, the tools used by each of the participating projects will be compared according to methodology, areas of application, constraints for usage, domains of applicability, etc. IIASA would play a major role in this comparison area.

(5) Development of New Models, Methodology and Concepts

This phase of the research represents one of the rewards - the possibility of the synthesis of the methodologies, of new concepts arising from the mutual exposure of the scientists to alternative concepts, of imaginative new research directions. At the present early stages of the research it is too early to predict what the payoff might be in this area. However, already it is clear that exchanges of models or model components are occurring.

(6) Multinational Workshop

The project will culminate with a five-day workshop at

IIASA tentatively scheduled for November 3-7, 1975. Cross-comparisons will be carried out with various combinations of models and policies applied to each of the regions. Participation in the workshop will include energy experts from each of the regions, IIASA scientists, and policy-makers from each of the regions. The workshop is described in Section IV below.

As indicated in Figure 2, there are certain feedback loops within the overall structure of the research program. New data systems and improved models will hopefully be the result of certain phases of the research program. In addition as shown in the diagram it would be possible for the project to have followup phases with other countries or regions becoming successively involved, using the collaboration of the first three countries as a prototype approach. During some of the earlier discussions on this research project, consideration was given to including a developing country in the follow-up phase. An additional suggestion was that the methodology be extended to other resources in addition to energy. These two considerations are under active discussion within the IIASA core group.

## III. A Proposed Disaggregation of Regional Energy Systems

To provide an initial working structure for the design of the research program, including (1) the evaluation and choice of models to be included in the research, (2) assessment of data availability, and (3) the formulation of appropriate policy questions, the components of an integrated energy system have been laid out according to the structure outlined in Table I.

The Wisconsin Regional Energy Model Served as a prototypical example of these components.

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Table I <u>A Descriptive Structure of An Integrated Regional Energy System.</u>

1. Energy Demand
    a. Economic Sector
    b. Physical Process
    c. Fuel Type
2. Energy Supply
    a. Fuel Type
    b. Source
3. Environmental
    a. Air
    b. Water
    c. Land
    d. Standards and Monitoring
    e. Public Health
4. Socio-Economic
    a. Demography
    b. Land Use
    c. Urban Design
    d. Fiscal Considerations

As a tentative basis for the more detailed structure of the research program, each of the macrocomponents in Table I is laid out in more detail in the following subsections. These structures are proposed as a vehicle for implementing comparisons of the case studies, data sets, models, etc. They should be viewed only as a starting point for discussion.

A. <u>Energy Demand</u>

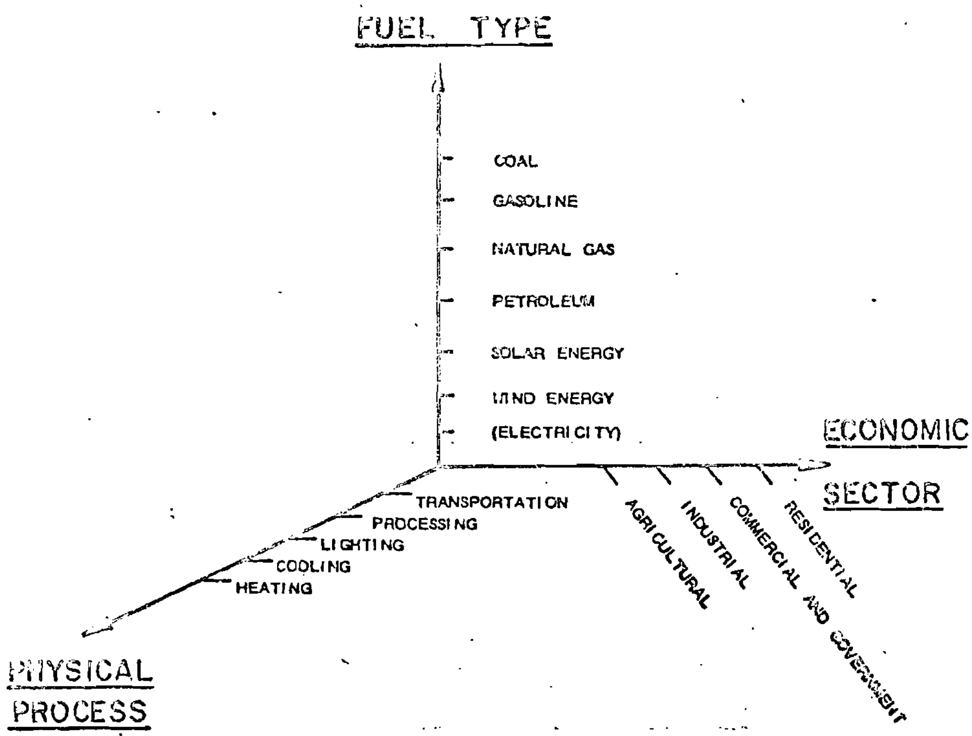
Each of the initial three regions would appear to have significantly different patterns of energy demand. Furthermore the demand forecasting and planning procedures in each of the three differ greatly. For this reason, a practical initial step is to provide a descriptive framework for the components of demand. A second step would then be the specification of the quantitative tools used to describe or forecast these demands in the future within a specific planning process at some level of disaggregation (which may differ from the level used for descriptive purposes). A third step is the examination of appropriate policy questions associated with energy demand. Each of these three steps or components of the demand question is described below:

(1) <u>Descriptive Structure</u>

A general descriptive structure is shown in Figure 3 where the demand processes are categorized according to economic sector, physical process, and fuel type. The differences and similarities in demand patterns across the regions should be of great value in developing the concept of national or regional "energy indicators"*, i.e. coefficients or parameters which could be useful indices in evaluating the state of a broad spectrum of energy systems.

In the descriptive framework of Figure 3, the question of dimensionality in time and space is a key one. An initial step (designated here as the zero level of complexity) would be to specify annual demands for each of the three regions.

Figure 3 Descriptive Structure of End-Use Energy Demand




*Within the more general context of environmental management, these are analogous to the "Ecological Reynold's Numbers" referred to by Holling (5).

A "first level" complexity would include more disaggregation in space in time, e.g. seasonal demands and demands according to urban and rural locations. These would be useful in evaluating approaches to land use planning. A second level of complexity might associate these demands even more explicitly with given societal activities. The appropriate choice and definition of these levels of complexity should evolve during the early stages of the research program.

(2) Comparison and Evaluation of the Energy Demand Models

One of the important outputs of this research will be a better understanding of the applicability of various demand modelling approaches under a wide range of conditions and of the need and opportunities for new techniques. As an initial basis for this discussion, the classification and descriptive framework suggested by Charpentier (6,7) at IIASA has proven very useful. Representative of the types of characteristics in his classifications are:

i) Type of Model

Econometric (Correlation)

Optimization

Simulation

Scenarios

Input-Output (Static and dynamic)

ii) Other Characteristics

Linkage to the economy

Linkage to supply

Disaggregation in time and space

Input Data Requirements (disaggregation, etc.)

Output

The linkage of these models to national and regional energy systems will be of great interest.

(3) Some Representative Policy Questions

Within the framework of the modelling and planning techniques used in the regions, several policy questions will be posed with the objective of evaluating the applicability of the array of policy analysis tools that emerge from the research. A few representative policy questions are:

- What effect would the phased introduction of specific techniques (e.g. greater reliance on mass transportation, (or the auto), modified building or urban designs, modified agricultural technologies etc) have on energy demands?
- What would be the consequences of a gradual and long term transition to a high, low or zero energy growth society (as described in the recent Ford Foundation's Energy Policy Project Report)?

B. Energy in the Agricultural Sector

Because of the special importance of food production, processing and distribution in the world today, and because of the important role which energy plays in the food system, special emphasis is being given to food-energy relationships within the Integrated Energy System Research Program.

(1) Major Objectives

The major objectives of the agricultural energy use comparison can be divided into two components:

(a) Descriptive - To examine the differences and similarities of energy use in the agricultural sector for the study regions. This would be done by looking at patterns of energy use in the crop production and the livestock production subsectors, and the interrelatedness of energy use between these two subsectors. If data permit, the food processing subsector energy use should be included here in agriculture. The relative division of energy use in each of the agricultural subsectors would also be described.

(b) Policy - To examine specific food-energy policy questions, e.g. what potential is there in these regions for energy conservation in the agricultural sector without causing a loss in crop yields and without greatly expanding crop acreage. Environmental considerations would play a role here, since some strategies of energy conservation might be more conserving of the long range ecological, productive potential of the land than others.

(2) General Overview

Figure 4 shows a sample block diagram of the types of components and pathways that could form the core of the agricultural sector's energy use comparison and analysis. In the diagram, direct energy use and indirect energy use are noted. Direct energy is, for example, the per hectare gallons of gasoline. Indirect energy is, for example, the energy required to produce fertilizer.

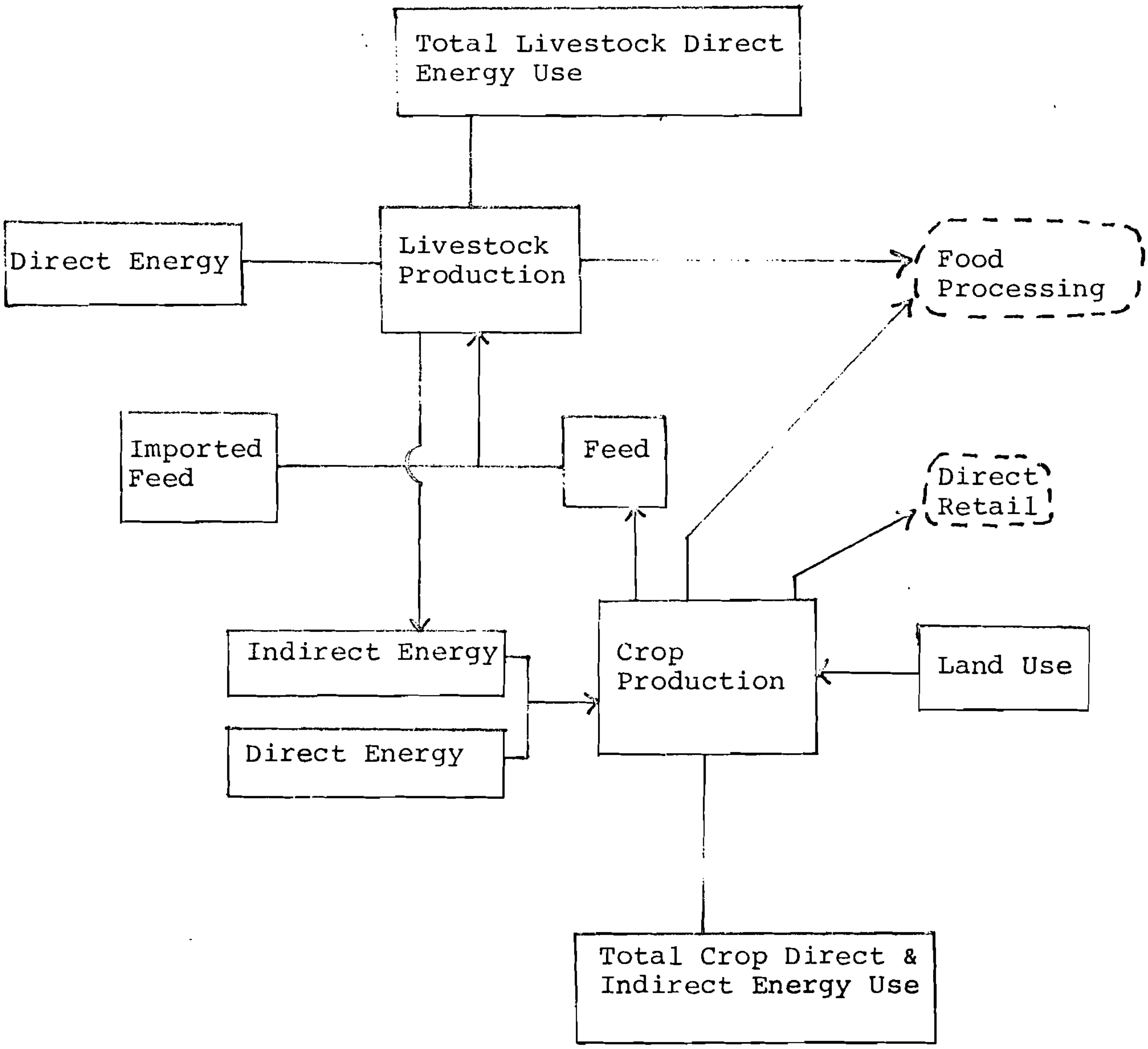



Figure 4    Agricultural Sector

There are four major areas of data of interest:

(a) Production and land use (e.g. hectares of land in each major crop and production for each major crop).

(b) Energy use per unit of production (e.g. gallons of gasoline/hectare/year, hours of labor input/hectare/year).

(c) Flow of agricultural material (e.g. agricultural production used locally, exported, imported, used for feed, or going to food processing).

(d) Food processing energy per unit of production (e.g. kcal/unit output or kcal/unit of value added).

It is felt that (b) above will be one of the most interesting and important data sets for an extremely meaningful study, yet it will be one of the most difficult data sets to develop.

C. Energy Supply

In the energy supply area, a research structure is suggested similar to that described above for demand, i.e. descriptive, model comparison, and policy analysis. Each of these three is described briefly below. The suggested descriptive structure, based upon previous work at IIASA, is presented.

(1) Descriptive Structure

In general, energy supply should be specified by type, origin, and special characteristics, e.g. energy content, important impurities such as sulfur content, etc. A reasonable time series of these data, as well as cost information over that time period, would be useful. For the purposes of some specific policy questions such as feasibility of district heating, energy recovery from waste products etc., some locational information might be useful.

(2) Comparison and Evaluation of the Energy Supply Models

As in the Demand Section above, there are several categories according to which the supply models can be described and compared. A more tightly structured comparison should evolve in the course of the study. Some initial steps are already underway in connection with two well-known supply models, the model developed by Finon et al at Grenoble (8,9) and a model developed and applied at IIASA (10). Both of these models are based upon optimization procedures involving linear programming techniques. It is proposed that these models can be examined for their applicability to the regional energy supply questions of interest here. The supply models in use at the Institut für Energetik in Leipzig (11) are also based upon optimization procedures; as further information about the Leipzig models become available, they will also be analyzed for general applicability in the regions.

To provide a basis for further discussion in the supply area, the basis of the IIASA supply model and the requirements for its application to the one or more regions is described here.

The IIASA Supply Model - If it is assumed that the energy system is comprised of m energy suuply categories (coal, oil, nuclear etc.) and n demand categories (transportation, household, etc.), then the question arises how to allocate the supplies in an optimal way to the demands. Here the term 'optimal' has to be defined still. It is clear that not every supply category can meet every demand (e.g. electricity cannot be used for air traffic) and in addition, there exist competitions for the supply as well as for the demand side. This means that boundary conditions have to be taken into account. Furthermore, if one considers a planning horizon over several years, and optimizes the allocation for each year separately, then changes in the allocation may occur which cannot be tolerated from some economical or other point of view. Problems of that kind may call for an iterative procedure.

The IIASA model has been developed by Häfele, Manne and Shikorr (HMS) for the study of the optimal supply of energy for a model society over a planning horizon of 75 years, going through a transition from fossil to nuclear fuels and using total discounted costs as an objective function. In a continuation of that work, Suzuki and Avenhaus (12) used Hoffman's demand estimates for the U.S. through the year 2000 (13) and analyzed if and under what circumstances the energy supplied by the HMS model could meet the energy demand of the different demand categories. In contrast to Hoffman's work and according to the HMS model, different points of time were considered. An illustration for the supply and demand categories used in reference is given in Figure 5. In addition Konno and Srinivasan (14), and Suzuki and Schrattenenholzer (15) have carried out numerical calculations in order to study the sensitivity of some of the more important parameters of the models. It is not appropriate to report here on the details of these results, but instead an outline is given to show what is necessary for similar studies which could be used for comparative

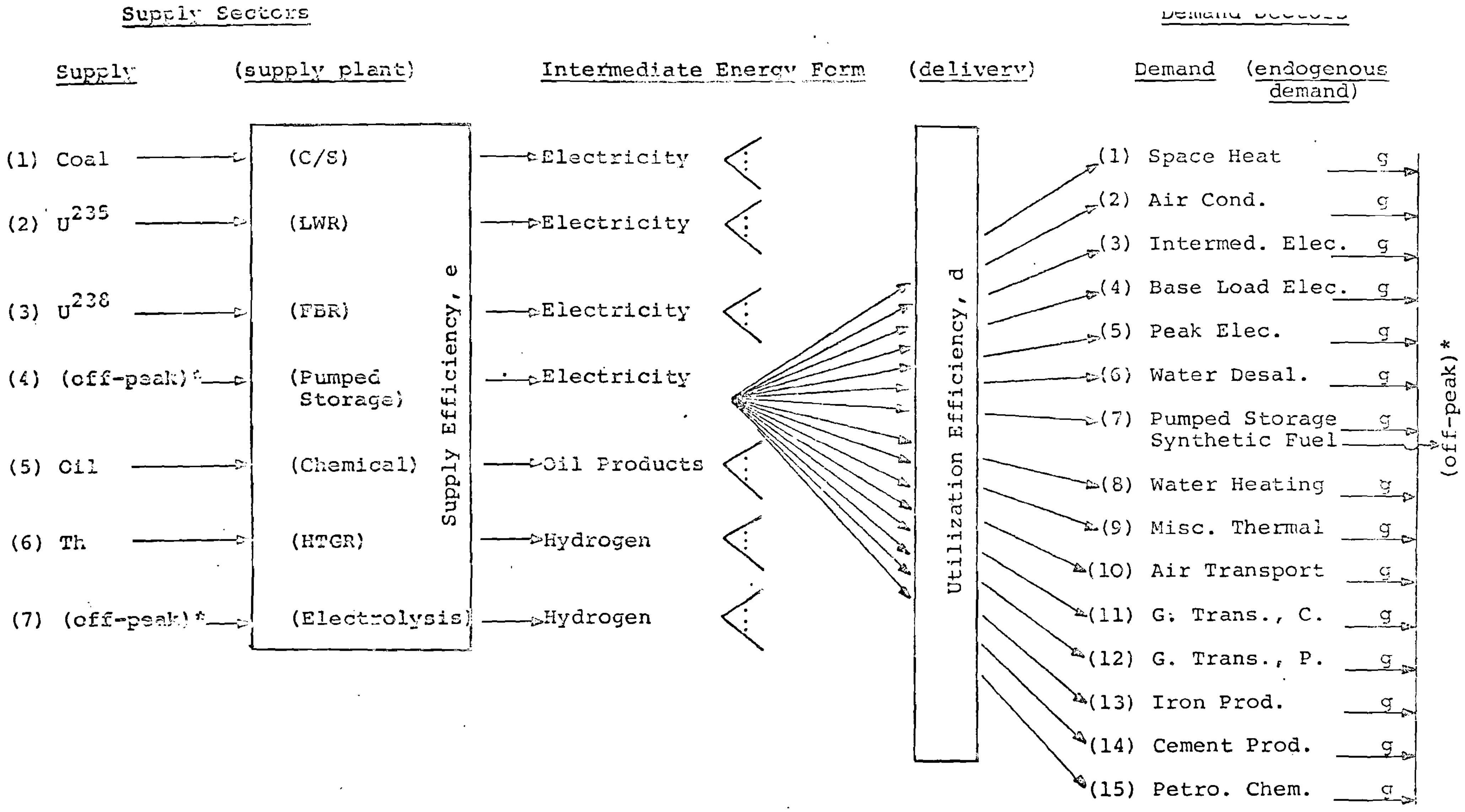



Figure 5 Schematic description of the format in the application of the IIASA Energy Supply Model (12).

purposes.

The following information and data are necessary to study supply problems along lines similar to those carried out at IIASA as described above:

i) Demand and supply categories have to be specified, depending on the degree of aggregation necessary and possible for the whole study, as well as projections for the totals of the supply and demand of the different categories over the whole planning horizon.

ii) The planning horizon as well as the time steps for the optimization procedure (e.g. 1975-2025, with 5 year time steps).

iii) The optimization criterion.

iv) The allocation coefficients from each supply to each demand category (e.g. unit cost if the optimization criterion were costs).

v) All the boundary conditions to be taken into account, both qualitatively and quantitatively, also projected over the whole planning horizon.

## D. The Solar Supply Option

Solar energy is emerging as a strong contender for playing a major role in future energy supply systems. For this reason, and because IIASA has an active research program investigating the several aspects of the solar supply option(16),it will be considered explicitly in this research program.

In prinicple solar energy can be converted via a large menu of technologies to heat, electricity, shaft horsepower and synthetic fuels. None of these has achieved the status of a fully commercialized technology with the exception, on a relatively small scale, of domestic water heating. Domestic solar water heating provides about one fourth the people in Isreal with hot water. Smaller but still substantial numbers of people in Latin America, Australia, New Zealand and Hawaii also use such devices. Solar space heating and cooling systems are now marketed in the United States and will soon also be marketed in Japan. Under some considerations (available front end capital, for example), such systems are cost effective on a life-cycle cost basis when compared with oil heating or all-electric resistive heating.

(1) Objectives

- To develop and evaluate research methodologies for the assessment of the potential of solar conversion systems in specific regions and human settlements.
- To test these assessment procedures in the regions collaborating in the Integrated Energy System Project.

(2) Methodology and Models

IIASA has made a major commitment to evaluating the solar energy option as a long term major energy source for mankind (16), with particular emphasis upon its application to European countries. An array of methodologies are being developed to implement the following evaluation tasks:

- Technical and economic characteristics of various solar conversion systems
- Land costs and availability; solar conversion system site identification

- inputs of large scale deployment of solar conversion systems

These methodologies developed at IIASA will be applied to the regions under study in the integrated energy systems project. In addition, solar energy expertise from some of the collaborating institutions will be utilized. In particular the Solar Energy Research Group at the University of Wisconsin (17) will provide expertise in the area of solar heating and cooling in buildings.

The general approach which is proposed for the Integrated Energy Systems Project is as follows:

(1) Data specification and collection for each region.

(2) Evaluation of siting potential in each of the regions, based upon technical, economic, and regional information.

(3) Development of scenarios for high, medium, and low technological implementation of solar energy systems of a long term planning horizon (~50 years) with particular attention to the overall energy supply system mix.

(3) <u>Preliminary Data Requirements</u>

It is believed that a zero order assessment can be made using the above approach within the time and resource constraints of this project. This would involve only a preliminary look at the availability of land, sunlight and water, as well as at the current and projected patterns of energy use. This would require the following types of information:

Land Use Patterns and Physical Geography

Types of land, e.g. agriculture, forests, pasture, settlements, etc.

Availability and economics of land

Climatic variables, e.g. precipation (type and amount), sunlight (direct and diffuse plus cloud cover indices), wind patterns (frequency and speed)

Soil Types and Slopes

General Information about the Infrastructure of the Regions, most of which would be in connection with the energy demand models (Section III.A of this working paper).

(4) Representative Policy Evaluations

Is solar energy at all feasible for each region?

Is any one particular solar technology more attractive and should it be investigated in more detail? Is further research warranted?

E. Environmental Impact

(1) Major Objectives

The major objectives of the environmental impact comparison can be divided into three components.

(a) Descriptive - To examine differences and similarities of the environmental impacts connected with energy use in each of the regions, looking for both intuitive and counterintuitive patterns of differences and similarities, given the different patterns of energy use in the regions compared.

This will be of interest to policy concerned with environmental impact forecasting and planning.

(b) Model Comparison - To compare and develop some "gross" measures of environmental impact that are meaningful in the assessment of policy and planning. For what measures is the Δ impact/Δ policy more easily differentiable, therefore, providing a better impact indicator for planning.

(c) Policy - To examine specific policy questions, e.g. what effect would certain environmental standards have on energy use, and to examine how environmental impact is viewed and assessed at the policy level in the different regions.

(2) A Structure for Impact Analysis

Figure 6 gives a proposed structure of the different pathways to be considered for an environmental impact analysis, with a key word or phrase for each step.

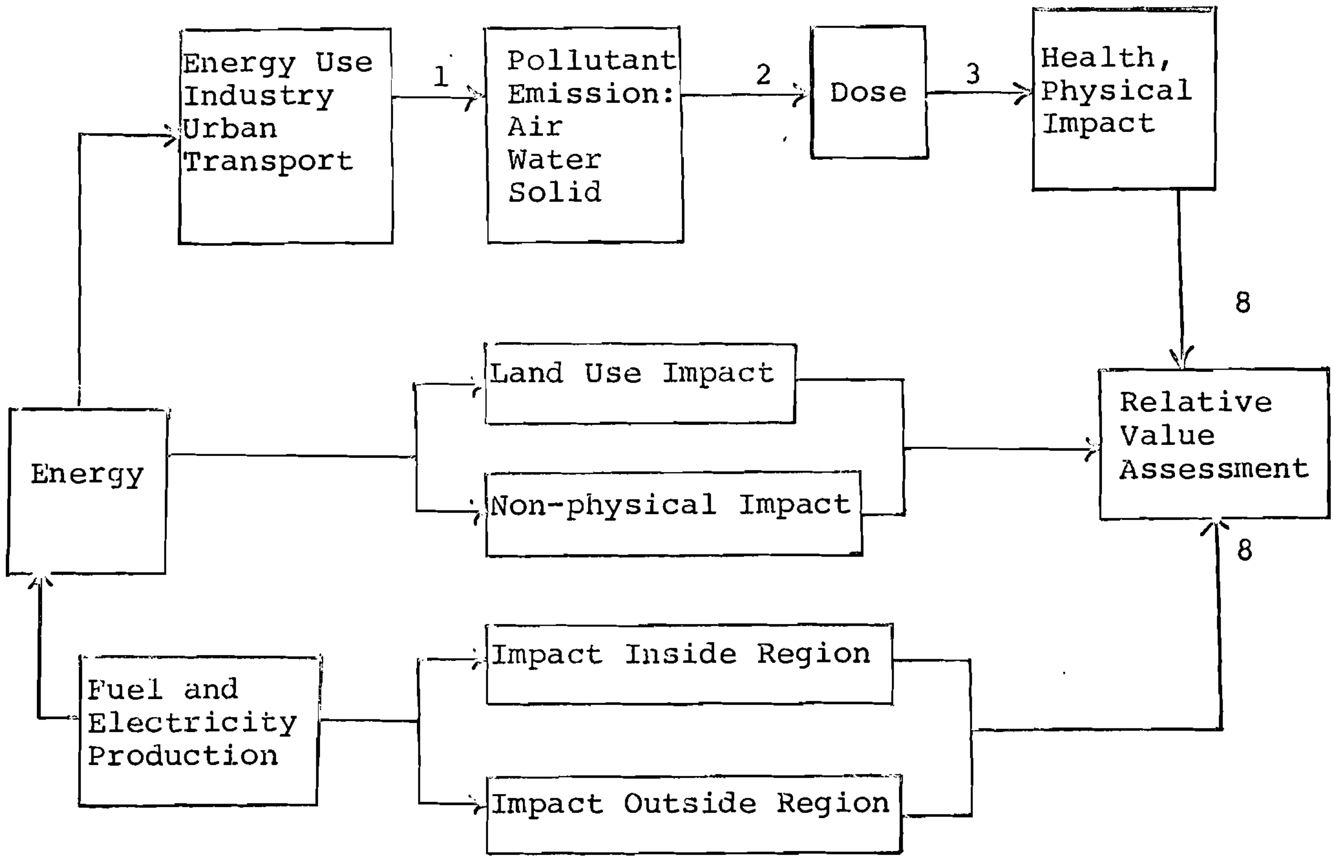
(a) Input Data - It would be most desireable to have data available to be able to evaluate each pathway 1-8 shown in Figure 6. General areas of data needs are:

(1) Geographical data (e.g. city population density)

(2) Meteorological data (e.g. wind statistics, atmospheric stability statistics)

(3) Pollutant emission data (e.g. emissions from tall stacks, emissions from space heating)

Figure 6 Pathways for Environmental Impact Analysis*




1 Emission

2 Dispersion

3 Dose-response

4 Direct land use

5 Direct economic effects

6 Fuel chain impacts, within the region

7 Fuel chain impacts, outside region

8 Value assessment

These pathways encompass three geographic scales:

(a) local impacts

(b) regional impacts

(c) impacts outside of the region due to use of energy <u>in</u> the region

The main emphasis is on the society and not the individual person

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*This structure is essentially identical to that used in the Wisconsin Regional Energy Model (18).

(4) Results of monitoring data (e.g. $SO_2$ measurements)

(5) Economic and fuel use data (e.g. different fuels used for space heating, value added)

(b) Output

Depending on the data available, the output could be one of several levels of complexity. For example, the within region output could be:

(1) Zeroth level - total emissions from each sector

(2) first level - zeroth level with simple dispersion

(3) second level - Zeroth and first levels with measurements and more complex dispersion considerations.

Additional output would be further impact attributes such as:

(1) potential health impact

(2) potential economic impact

(3) severity of impact vs. importance

(4) short term vs. long term impacts

(5) societal vs. individual impacts

(6) geographic distribution of impacts

(3) Typical Policy Questions

Policy questions have several levels of complexity. For example:

(a) first level - What consequences would environmental standards have for energy use?

(1) with zeroth level output above?

(2) with first or second level output above?

(b) second level - For a given set of dispersion and cost information, what would be an economically optimal standard?

## IV. Tentative Preparation and Structure of Major Workshop

As described in Section II, the final stage of the First Phase of this project would be a major comparative workshop. This workshop is scheduled for November 3-7, 1975. In the workshop, which will be preceded by several months of model and data preparation, etc., cross-comparisons will be carried out with various combinations of models and policies applied to each of the regions. Table II below gives the general picture of the nature of the workshop.

It is believed that the examination of these scenarios for three or more regions, each differing greatly in their energy systems characteristics, can lead to a much better understanding of the systems themselves and the methodologies with which we study the systems. If only partial success is achieved in the objectives, then the results of this research will be extremely valuable in moving on to other resource systems, including not only those of industrialized nations but also pointing toward systems analysis of energy and other resource systems in the developing countries. It is this later point that is implied in part C of Item 6 below, "global feasibility maps", that is, the extension of these systems analysis methodologies to other regions of the world.

Table II. Proposed Structure of Multinational Workshop

1. Basic Method of Cross Comparison

| Region | Regional Group A | B | C |
|---|---|---|---|
| I | | | |
| II | | | |
| III | | | |

2. Energy System Components Considered

| | Regional Group A | B | C |
|---|---|---|---|

(a) Ext. World

1. Fixed
2. Driven by World Model, etc.
3. ⋮

(b) Energy Demands

1. Aggregated
2. By sector and processes (e.g. agriculture,heating)
3. By fuel
4. Feedback from supply

(c) Supply

1. Primary fuel
2. Secondary (e.g. electricity)
3. ⋮

(d) Environmental Impact

1. External to region
2. Internal
3. Land use

(e) Socio-economic

1. Population
2. Jobs/Energy indices
3. Energy costs
4. ⋮

3. Standardized Data Base

(Developed and distributed well before workshop)

| | Region I | Region II | Region III |
|---|---|---|---|
| a. Energy Demands | | | |
| b. Supply | | | |
| c. Socio-economic variables | | | |

4. Possible Basis for Comparisons of Models and Policy Analysis Methodology

(a) Similarity or differences in short and long range projections

(b) Effects of disaggregation levels

(c) Effects of special components, e.g. feedbacks (price, environment?) between supply and demand

(d) Breadth and depth of policy alternatives accommodated

5. Types of Recommendations to be Produced

(a) Data adequacy and needs

(b) Disaggregation and feedback

(c) Critically sensitive areas

(d) Breadth of options analyzable

(e) Implications of alternate policy objectives

(f) Research priorities

6. Output of Workshop

(a) Proceedings of workshop including data bases, models, evaluations, policy tests, comparisons, recommendations, etc.

(b) Recommendations for further research, possible followup workshop extension to other countries.

(c) Global feasibility maps for applications of this approach to other regions, including developing countries.

## V. Proposed Schedule for the Research Project

One of the criteria listed in Section 1 was that a project be implemented on a time scale consistent with IIASA's "stability and resilience" characteristics. Presented below is a preliminary schedule for this project.

| | |
|---|---|
| Jan - Feb. 15, 1975 | Project definition and preplanning at IIASA |
| Feb. 17-20 | Planning Session with University of Grenoble |
| Feb. 20 - March 10 | Exploratory planning session with Institut für Energetik, Leipzig |
| Late March | Report from Grenoble on Adequacy of data for Rhone-Alp Region |
| Early April | Exploratory sessions with other potential participating regions |
| Mid-April | Small one-day working session in Vienna with representatives from each participating country |
| | Definition of areas of model comparison, data requirements, hypothetical policy questions. |
| May 1 | Working Paper describing project, structure, objectives, etc. |
| May 19-23 | Research meeting at IIASA during IIASA Workshop on Energy Demand |
| July 1 | Preparation of a major paper for first day of 1975 IIASA conference |
| November 3-7, 1975 | Major workshop with the 3 countries participating, including policy makers. |
| November, December, 1975 | Publication of workshop proceedings; Evaluation of First Phase of project; Transition to Followup Phase |

## References

(1) Mesarovic, M. and E. Pestel, "Multilevel Model of World Development System," Preceedings of an IIASA Symposium, SP-74-5, April 29-May 3 1974.

(2) Häfele, W. "Future Energy Resources." International Institute for Applied Systems Analysis, IIASA RR-74-20, November 1974.

(3) Foell, W.K. "A Long-Range View of the Energy Crisis." Paper Presented at Conference on the Implication of the Energy Crisis. Milwaukee, Wisconsin, March 1973.

(4) Foell, W.K. "The Wisconsin Energy: A Tool for Regional Energy Systems and Policy Report No. 10." Institute for Environmental Studies, University of Wisconsin-Madison, November 1974.

(5) Holling, C.S., and M.B. Fiering. "Management and Standards for Perturbed Ecosystems." International Institute for Applied Systems Analysis, IIASA RR-74-3, February 1974.

(6) Charpentier, J-P. "A Review of Energy Models." International Institute for Applied Systems Analysis, IIASA RR-74-12, July 1974.

(7) Charpentier, J-P. "Overview of Techniques and Models Used in the Energy Field." International Institute for Applied Systems Analysis, IIASA RM-75-8, March 1975.

(8) Finon, D. "Optimization Model for the French Energy Sector." <u>Energy Policy</u>, Vol.2, June 1974.

(9) Finon, D. "An Aggregate Approach to the Energy Problem: An Optimization Approach for the French Energy Sector". <u>Energy Systems Forecasting, Planning, and Pricing,</u> Ed., C.J. Cicchetti and W.K. Foell, University of Wisconsin Press (In Press).

(10) Häfele, W. and A.S. Manne."Strategies for a Transition from Fossil to Nuclear Fuels".International Institute for Applied Systems Analysis, IIASA RR-74-7, June 1974.

(11) Hätscher, W. and Scientific Staff, Institute für Energetik, Leipzig, March 19, 1975

(12) Suzuki, A. and R. Avenhaus."A Study of the Demand Aspects of the Häfele-Mann Model - An Application of the Mathematical Technique of the Hoffman Model."International Institute for Applied Systems Analysis, IIASA RM-75-4, Februray 1975.

(13) Hoffman, K.C. "The United States Energy System - A Unified Planning Framework." Unpublished Doctoral Dissertation, Polytechnique Institute of Brooklyn, June 1972.

(14) Konno, H. and T.N. Srinivasan. "The Häfele-Manne Model of Reactor Strategies: Some Sensitivity Analysis". International Institute for Applied Systems Analysis, IIASA, RM-74-19, October 1974.

(15) Suzuki, A. and L. Schrattenholzer. " Sensitivity Analysis on Hydrogen Utilization Factor of the Häfele-Manne Model." International Institute for Applied Systems Analysis, IIASA Rm-74-30.

(16) Weingart, J. "Evaluating the Solar Energy Option as a Long-Term Major Energy Option for Mankind," International Institute for Applied Systems Analysis IIASA WP-74-43. September 1974.

(17) Beckman, W.A. and J.A. Duffie, "The Energy Crisis and Energy From the Sun". in Symposium on Solar Energy Utilization", Washington, D.C., September 30 1974.

(18) Buehring, W.A., W.K. Foell, and R.L. Dennis, "Environmental Impact of Regional Energy Use: A Unified Systems Approach". _Energy Systems Planning, Forecasting and Pricing_, Ed. C.J. Cicchetti and W.K. Foell, University of Wisconsin Press (In Press).