PN-ABS-535

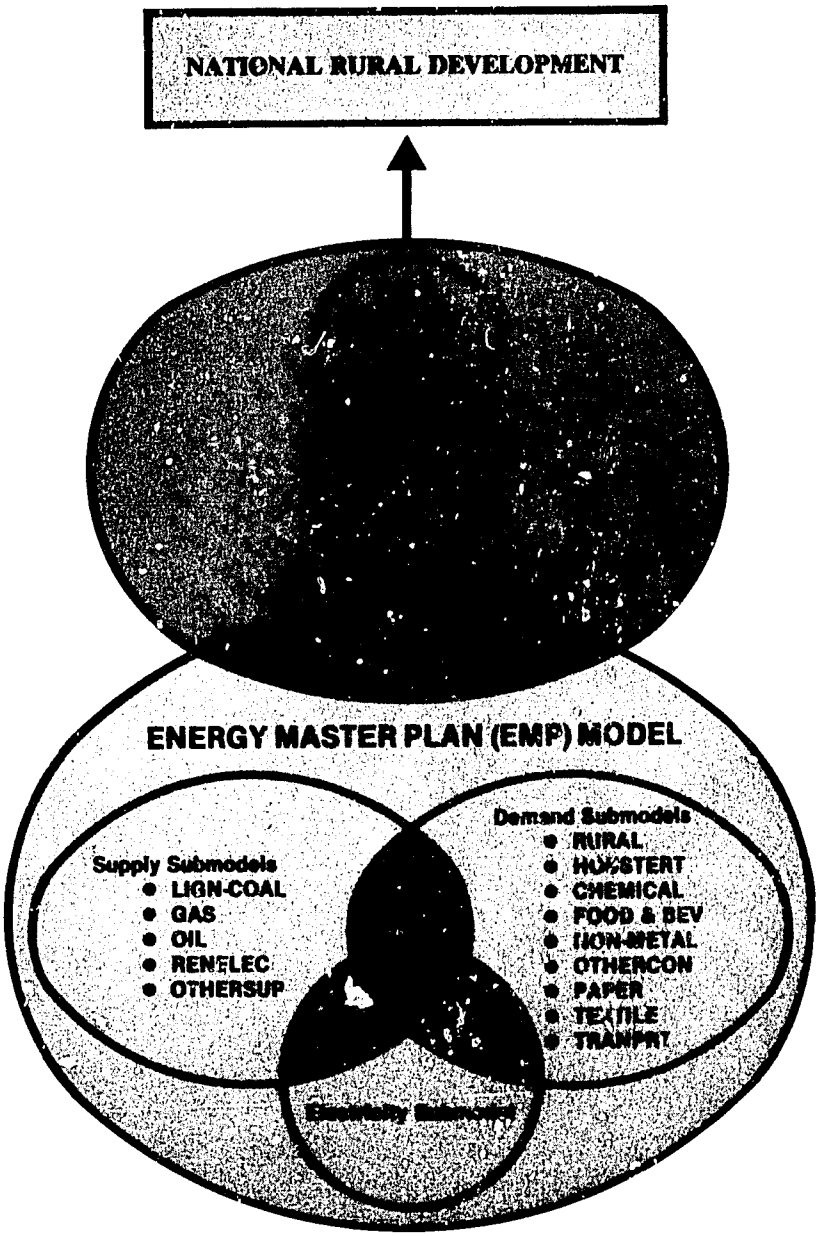
ISN 39504

SECTORAL ENERGY PLANNING MODELS: SUPPORTING STUDIES OF THAILAND'S ENERGY MASTER PLAN

Submitted to the
National Energy Administration
Ministry of Science, Technology and Energy

Under the
Renewable Nonconventional Energy Project
Royal Thai Government
U.S. Agency for International Development

Relationships Among Models and Submodels of the Energy Master Plan



ACKNOWLEDGEMENTS

Acknowledgements are made to Mr. Prapath Premmani, Secretary General, Mr. Tammachart Sirivadhanakul, Deputy Secretary General and Mr. Sompongse Chantavorapap, Project Manager from the National Energy Administration (NEA). Dr. Maurice L. Albertson, Senior Technical Project Management Expert, Ms. Lana Larsen and Ms. Marcia Hamilton, Editors, from the Office of Project Management Support; Mr. Supot Tadyu from NEA; Dr. Techapun Raengkhum, Dr. Poonsanga Somboonpanya, Dr. Achana Wattananukit, and Mr. Pongsa Pornchaiwiseskul the Consulting Team; and Ms. Chutiwan Dumrongpanich are also recognized for their efforts in producing this report.

Gratitude is deeply expressed to the U.S. Agency for International Development (USAID) for providing financial support and to the Department of Technical and Economic Cooperation (DTEC) for its cooperation.

Mr. Kriengkorn Bejraputra
Component Leader and Author
Energy Policy and Planning Division, NEA

CONTENTS

	page
Acknowledgements	5
Table of Contents	7
Executive Summary	9
List of Tables	21
List of Figures	22
CHAPTER 1: INTRODUCTION	
A. Historical Background of the Energy Master Plan	25
B. Energy-Economic Planning	27
C. Objectives of Study	36
D. Significance of Study	38
E. Scopes of Work	40
CHAPTER 2: REVIEW OF THE ENERGY MASTER PLAN MODEL AND THE BASELINE SURVEY	
A. Energy Master Plan Model	45
B. Baseline Energy Survey	48
CHAPTER 3: ENERGY MASTER PLAN SUBMODELS (EMPS)	
A. Energy Master Plan Submodels Understudy (EMPS)	53
B. Rural Energy Use Model	55
C. Transportation Submodel	102
D. Electricity Submodel	112
E. Textile Industry Submodel	126
F. Paper Industry Submodel	136
G. Urban Household and Tertiary Submodel	138
H. Conclusions	140
I. Recommendations	140
CHAPTER 4: RURAL ENERGY MODELS	
A. Household Energy Model	145
B. Rural Community Development Model	166

Previous Page Blank

CONTENTS (continued)

Page

CHAPTER 5: DISCUSSION OF RESULTS

A. Energy Master Plan Submodels 205

B. Rural Energy Models 207

CHAPTER 6: CONCLUSIONS

A. Energy Master Plan Submodels 219

B. Rural Energy Models 220

CHAPTER 7: RECOMMENDATIONS

A. Energy Master Plan Submodels 225

B. Rural Energy Models 227

REFERENCES 231

EXECUTIVE SUMMARY

A. INTRODUCTION

In order to cope with energy problems in Thailand in a detailed, systematic and comprehensive manner, two important studies were undertaken--the Energy Master Plan of Thailand (EMP) and the Renewable Nonconventional Energy Project.

The Energy Master Plan of Thailand (EMP) was commissioned in 1980 under the sponsorship of the Asian Development Bank (ADB) and the United Nations Development Program (UNDP). The major objective was to equip the National Energy Administration (NEA) with tools to do macro energy planning and prepare a long-range, sector-wide energy plan for Thailand "with a view to reducing the growing dependence of energy supply on the import of petroleum products and devising and implementing effective, appropriate measures for improved management of energy demand".

The Renewable Nonconventional Energy Project was commissioned in 1980 under the sponsorship of the U.S. Agency for International Development (USAID). The major objectives were to assist the Royal Thai Government (RTG) work toward reducing importing energy resources, arresting environmental degradation due to deforestation, and creating increased income opportunities in rural areas. This was to be carried out through:

- Developing RTG institutional capacity to perform and sustain energy policy planning;
- Introducing and testing renewable energy technologies in rural areas; and
- Developing and testing techniques for disseminating such technologies.

In essence, the Renewable Nonconventional Energy Project has two reinforcing components:

1. An institutional development emphasis, and
2. The testing, adaptation and dissemination of renewable energy technologies relating to rural needs.

This report is a part of the Energy Master Plan Support Component of The Renewable Nonconventional Energy Project. It summarizes the following studies:

- Meta Systems Inc.: Energy Master Plan Component Renewable Nonconventional Energy Project;
  Vol. I Rural Energy Planning
  Vol. II Rural Energy Use Model
  Vol. III Village Energy Model

- T. Raengkhum and P. Somboonpanya: Development of EMP Submodel

- T. Raengkhum, P. Somboonpanya, A. Wattanakit and P. Pornchaiwiseskul: Rural Community Development Model

These three studies can be separated into two main groups. One group contains Energy Master Plan Submodels (EMPS) concerned with augmentation and improvement of the EMP submodels. The Energy Master Plan Submodels include the Rural Energy Use Model and the EMP submodels (which study the subsystems of transportation, electricity, the textile industry, the paper industry, and the Urban Household and its tertiary subsystem). The other group contains the Rural Energy Models which include the Household Energy Model (HEM) and the Rural Community Development Model (RCDM).

B. OBJECTIVES OF THE STUDY

The six major objectives of the three studies were:

1. To strengthen RTG institutional capacity, particularly the NEA, to perform and sustain energy policy planning;

2. To support and supplement activities for the EMP study, particularly in the renewable energy area relating to rural needs;

3. To equip the NEA with tools for its required sectoral energy planning. Particular emphasis is given to rural energy planning;

4. To develop Job Control Language (JCL) for NEA's Remote Job Entry (RJE) terminal in order that data for EMP could be entered at the NEA's RJE terminal in utilizing the computer at the National Statistical Office (NSO);

5. To improve the rural energy sector in the EMP study by constructing a Rural Energy Use Model to meet the requirements of more comprehensive rural energy planning than was possible on the basis of the existing EMP study. Besides, the model should be operated, analyzed and interpreted separately and independently from and, moreover, consistently with the EMP study. Inclusion of such separate, independent subsystems are also needed in the development of EMP submodels such as transportation, electricity, the textile industry, the paper industry, and the Urban Household and its tertiary subsystem; and

6. To construct the Household Energy Model and the Rural Community Development Model in order to simulate the decision-making process for the best allocation of resources at the micro levels of planning: household and community. Particular emphasis is on rural development and rural energy planning.

C. SIGNIFICANCE OF THE STUDIES

It is expected that these three studies will:

- Help strengthen NEA in performing and sustaining effective energy policy planning. Particularly in rural energy planning, energy strategies can be planned in a more detailed and comprehensive manner such that acceleration of rural development, improvement of rural life and better income distribution (prime objectives of Thailand's fifth five year development plan (1982-1986)) can be achieved successfully;

- Equip NEA with tools for sectoral as well as macro energy planning. Therefore, construction, operation, analysis and interpretation of the sectoral model will be easier than the EMP study. Moreover, coordination with the agencies on the concerned subsystem or sectoral subsystem as well as data design and collection, can be done more effectively.

- Make more effective the coordination of sectoral energy planning and macro energy planning because the same methodology and software will have been used in both levels of planning.

- Provide a better understanding of the rural household and rural community's decision-making process. Thus, rural development and rural energy planning can best be achieved.

D. METHODOLOGY

The following is a brief overview of the methodology used in these studies.

Systems and Subsystems

All systems, including energy systems, can be broken down into components or elements--called subsystems. Accordingly, in this report, a "system" is the collection of subsystems which are the parts of the system discussed. Developing a system is the first step in developing a model.

Models and Submodels

A system can then be converted to a model. A model is built to represent the system, taking into account characteristics of the system. For example a mathematical model expresses a quantitative relationship of components of the system under study. Similarly, a subsystem can be represented by a submodel.

Linear Programming

All studies as well as the EMP used the linear programming model. Maximization of income and minimization of energy supply, costs etc. could then be analyzed.

Sensitivity Analysis

Sensitivity analyses on structural and nonstructural changes to answers of "what...if" kinds of questions were simulated.

Software

All studies except the Household Energy Model used the same software as the EMP study (although the same software as the EMP study could also be used for the Household Energy Model).

EMP Submodel Improvement

In constructing and improving the submodels of the EMP (such as the Rural Energy Use Model and other EMP submodels under study--the subsystems of transportation, electricity, textiles, paper industry and urban household and its tertiary subsystem) that can be operated independently from and consistently with the EMP model (or in a weakly linked mode), a subsystem was selected and extracted from the EMP model. The additional links were added to improve the details of the subsystem.

It should be noted that the relevant 'ANCILLARY' and 'BY-PRODUCT' parameters must also be included in the subsystem considered. This is handled by creating supply nodes for relevant 'ANCILLARY' parameters and demand nodes for 'BY-PRODUCT' parameters. Any node number that is not used can be assigned. In the Development of the EMP Submodel Study, for example, node '000' and '999' were assigned to supply nodes for the relevant 'ANCILLARY' parameters and for demand nodes for the relevant 'BY-PRODUCT' parameters respectively.

Next, the upstream nodes for the subsystem considered were linked to any node that was not used or node '000'; appropriate purchase or shadow prices from the EMP optimization results would then be assigned to the link. On the final downstream nodes of the subsystem considered, which would otherwise connect with other nodes of EMP model, the flows had to be assigned.

To be consistent with the EMP, the shadow prices and flows mentioned above were to come from EMP optimization results.

It should also be noted that additional links for improvement of the details of the subsystem considered were performed, when possible,

depending on data availability, computer software/hardware limitations and the art of model construction.

Using the above procedure, the submodel built and improved was operated not only in conjunction with but also separately and independently from the EMP model.

The Rural Energy Models. The Household Energy Model and the Rural Community Development Model

The Household Energy Model and the Rural Community Model are also linear programming models constructed by combining the essential characteristics of the agricultural, animal husbandry, household, crop processing, animal processing and industrial models. After incorporation an analysis of energy flows at the household or community level was able to be performed. Normally, net income was maximized in the decision-making process when choosing among different sources of energy, allocating the energy to different activities, and selecting the conversion and end-use technologies for these activities. The resources available to the household and community were specified by the analyst.

Details of the Rural Energy Use Model, and development of the EMP submodels, Household Energy Model and Rural Community Development Model (including their data, computer data base, analysis and results) are explained in the main report.

E. THE USEFULNESS AND POTENTIAL APPLICATIONS OF SECTORAL MODELS

The following four points summarize the usefulness and potential applications of energy submodels.

1. The sectoral submodels can be run not only in conjunction with but also separately and independently from the EMP model. This saves much computer time. Submodels can be improved more easily because computer software only has enough room for the sectoral submodels, as such, not the entire EMP model.

2. A sectoral submodel can be explained more easily and interpretation of it is much easier than of the whole EMP model. So is analysis; yet sectoral submodel results are consistent with the whole EMP model at the macro level.

3. Data base design and data collection can be easily implemented for each sectoral submodel. Agencies concerned with any sectoral submodel understand the need for quick data collection and thus cooperation and communication among various agencies will become more effective.

4. Improvement, interpretation, understanding, analysis and data collection of each submodel can be done quickly at low cost, including computer cost. Because each model can be worked out independently and separately from the whole EMP, the scale of work is considerably reduced.

CONCLUSIONS

Energy Master Plan Submodels

Rural Energy Use Model

The Rural Energy Use Model has been successfully developed as a macro-planning model for rural energy use and is particularly consistent with the whole EMP model. Test runs have also been successful.

Analysis of the Rural Energy Use Model suggests improvements in the charcoal kiln and rapid forest depletion problems. Forest plantation projects therefore need to be seriously considered for energy policy.

Other sources of energy supply are crop residues, dung, and other rural wastes.

Collection and travel time for fuelwood is a good indicator for abundance or scarcity of forest supply in most rural regions of Thailand.

Transportation Submodel

The transportation subsystem has been successfully developed as a macro-planning model for energy use in transportation and is particularly consistent with the whole EMP model. Test runs have also been successful.

Substitutions among modes of transport need further study.

There is great potential for energy conservation in this sector.

Electricity Submodel

The electricity subsystem has been successfully developed as a macro-planning model for energy conversion, distribution, and transmission in the electricity subsector, particularly with the whole EMP model. Test runs have also been successful.

Textile Submodel

The textile subsystem has been successfully developed as a macro-planning model for energy use in textile production.

There is great potential for energy conservation in this sector.

Paper industry Submodel

The paper industry subsystem has been successfully developed as a macro-planning model for energy use in paper production.

There is great potential for energy conservation in this sector.

Urban Household and Tertiary Submodel

Due to time limitations, this analysis was not made and, therefore, no conclusions were reached.

Rural Energy Models

Household Energy Model

The basic parameters for the Household Energy Model (HEM) have been developed, based initially on a basic household profile. The HEM covers activities related to agriculture, animal husbandry, crop processing, household, sources of energy, conversion of energy, and net income.

Data used in testing the model were obtained from several sources since an information/data bank for rural households does not exist. Many data items are based on regional data which the Study Team believes could be applied well to the household under study.

Community data and information used for testing the model were obtained from the surveys. Although the collection of data and information were not designed for the use of the HEM, the Study Team believes that they are accurate--to some extent.

A matrix generator and an MPSX were used as tools in formulating and solving linear programming problems for the rural household. Model alternative analysis as well as sensitivity analysis runs were conducted for a base case.

A Household Energy Model (HEM) has been sucessfully developed. It has been tested by using prototypical data as well as actual data obtained from selected households. The tests assure the applicability of the model which is used for household planning and/or assessment of rural household alternative activities. Major activities of rural household environments have been incorporated in the model developed.

Test runs concentrated on selected households. From the results obtained, it was found that the model developed could provide answers to questions concerning alternatives to household activities.

Analyses of resource utilization alternatives for selected households were made. It is expected that the selected rural households can be wisely developed using appropriate technologies and strategies formulated according to guidelines based on the results obtained from the HEM.

Rural Community Development Model

A Rural Community Development Model (RCDM) has been sucessfully developed. It has been tested and the tests assure the usefulness of the model which can be used for planning and/or assessment of rural community development projects. Major economic sectors in rural community environments have been incorporated in the developed model.

The RCDM data base was initially developed using a basic community profile. It has been expanded to cover activities related to renewable energy projects as well as the Government's key activities in its rural development plans.

Data used in testing the model were obtained from several sources since there is no existing information/data bank for rural communities. Many data items are based on regional data which the Consulting Team believes could be applied well to the communities being tested.

Community data and information used for testing the model were provided by the NEA from the surveys. Some data and information were also obtained from the investigations of the Consulting Team during a short visit to the communities. Although the collection of data and information were not specifically designed for the use of RCDM, the Consulting Team believes that it is accurate to some extent.

FINERG software was used as a tool in formulating and solving linear programming problems for rural community development. Alternative runs were conducted for base case as well as alternative cases and sensitivity analyses.

Test runs concentrated on the 2 selected communities. From the results obtained, it was found that the model developed could provide answers to questions concerning development projects.

Suggestions on development strategies for the 2 selected communities were made. It is expected that rural communities can be wisely developed using selected appropriate technologies and strategies to be formulated based on the results provided by the RCDM.

RECOMMENDATIONS

The Energy Master Plan Submodels

Rural Energy Use Model

Data Base Improvement. Collection, organization and categorization of existing and incoming data are recommended; it is also necessary that these factors be included in a coherent structure designed for systematic planning and policy analysis.

The design of the data base for rural energy use is therefore needed. However, the Rural Energy Use Model does provide a useful guide to an extended data collection activity, particularly in fuelwood/charcoal demand and supply, fuel prices, device efficiencies, rural industry, and costs of new sources and technologies.

Scenario and Policy Analysis. Answers to "what...if" types of questions in model simulation, analysis and interpretation should be analysed with plausible scenario assumptions.

Shadow Prices. In-house training for NEA staff on shadow price interpretation and policy formulation would be very useful for bridging the communication gap with NESDB, Ministry of Finance and the Budget Bureau.

Demand Projection. Due to data limitations and basic research in this rural energy field, no economic elasticity concept is used. NEA should therefore continue to improve demand projection methodology.

Transportation Submodel

Transportation Master Plan. A transportation master plan should be developed, focusing particularly on spatial-dynamic theories and substitution among modes of transportation.

Expansion of Transportation Submodel. Since the transportation master plan is not available, the transportation submodel should be expanded and improved as much as possible. Possible improvements are detailed in Chapter 3.

Data Bank for Transportation Subsystem. It is recommended that a data bank should be designed for use in both the Ministry of Communication and the NEA.

Electricity Submodel

A Cost minimization model of electric capacity, and a transmission expansion model should be developed along the lines of the spatial-dynamic model.

Expansion of Electricity Subsystem. Whereas recommendations for the transportation master plan are not developed, expansion of the electricity submodel should be improved as much as possible. Possible improvements are detailed in Chapter 3.

Data Bank for the electricity subsystem. This data bank should be designed for use in engineering, financial and economic analyses.

Textile Submodel

Expansion of Textile Subsystem. Major activities in textile activities that are not included (e.g., spinning, weaving, knitting, and finishing of garments, man-made fibres, spines and nets, textile yarn, blankets, socks etc.) should be added.

Data bank for textile subsystem. This data bank should be designed for use in both the NEA and economic planning.

Paper Industry Submodel

Expansion of the Paper Subsystem. The paper industry demands that the forecast be diversified and include more types of paper such as kraft paper, paper board, print paper, writing paper, hygiene paper, etc.

Perhaps the paper industry should be linked with the sugar industry subsystem. This would provide an opportunity for study of the use of bagasse as fuel or raw material in the sugar industry.

Data Bank for paper industry subsystem. This data bank should be designed for the use of the Ministry of Industry, the NEA, and economic planners.

Urban Household and Tertiary Submodel

Due to time limitations, the analysis was not conducted and therefore no recommendations are given.

General Recommendations

Data Base Improvement. Collection, organization and categorization of existing and incoming data are recommended; it is also necessary that these factors be included in a coherent structure designed for systematic planning and policy analysis.

Cooperation. Cooperation among various agencies is needed and responsibilities should be assigned.

Training. NEA staff should be trained to use computerized data bases and in data base design.

Scenario and Policy Analysis. Answers to "what...if" types of questions in model simulation, analysis, and interpretation should be analysed with scenario assumptions. Consistent planning should be adhered to in each level of planning, particularly in the field of energy.

Shadow Prices. In-house training for NEA staff on shadow price interpretation and policy formulation would be useful for bridging the communication gap with NESDB, Ministry of Finance, Budget Bureau, and other energy agencies. This would ensure that planning and policy formulation among government agencies is well coordinated.

Demand projection. Elasticity and advanced quantitative analysis concepts should be introduced; due to data limitations, basic research in the energy field is inadequate.

In-house training on methodology should be given to NEA staff.

In this way, the demand subsystem of the EMP can be considerably improved as suggested, for example, in the textile and paper subsystems.

Expansion of Submodels. Expansion of submodels in the EMP in order to cover mission activities should be constantly worked on by NEA staff.

The Rural Energy Models

Household Energy Model

HEM basic activity parameters should be expanded to cover activities which are not included in the existing model structure. This will facilitate planners in conducting studies when additional activities are examined as potential projects for household development.

A data bank for the HEM parameters should be established. This task would require multidisciplinary efforts of expertise in specialized fields. Careful analysis of the data required for HEM parameters would substantially reduce efforts in data collection for the individual household under study. Data which are homogenous in the village or region should be identified and used for the household under study.

Data required for a household should be analyzed. A questionnaire should be designed for the collection of data at the household level. This should be done by avoiding the collection of data at village and regional levels which are applicable at the household level. The collected household data should be kept in the data bank.

If necessary and, if possible, additional operations using the HEM should be investigated and developed. Specifically, a systematic way to change a linear programming matrix should be generated if some parameters are required to be changed. This will substantially reduce computer time required for an alternative run once an optimal feasible solution has been obtained. The report format of HEM should be investigated and developed to provide convenience in analyzing results.

The HEM should be used to analyze incomes of rural households in a way that will allow for different uses of resources, labor, and technologies. The model developed should be applied to household planning and/or assessment of household alternative activities, both energy and non-energy, at a household level in rural areas. This could be done by setting up priorities of household classes for the analysis.

Further analysis on the selected households in this study should be conducted. Perhaps additional households in different villages should be selected for model testing.

Analyses made by the Study Team on the testing of alternatives for the selected households should be used as the guideline in studying future households.

Rural Community Development Model

The RCDM should be used to maximize incomes of rural communities in such a way that resources, labor, and technologies will be used in an efficient manner. The model developed should be applied for the planning and/or assessment of Government projects, both energy and non-energy, at a community level in rural areas. This could be done by establishing priorities of communities.

The RCDM basic data base should be expanded to cover development activities which are not included in the existing data base. When activities are likely to be included in a potential community development project, this information should be input beforehand to help planners conduct future studies.

A data bank for the RCDM data base should be established. This task would require multidisciplinary efforts of expertise in specialized fields. Careful analysis of the data required for an RCDM data base would substantially reduce efforts in data collection for individual communities under study. Data which are homogenous should be identified and used for the community under study in the area.

Data required for a community should be analyzed. A questionnaire should be designed for the collection of data at the community level. This should be done by avoiding collecting data at the regional level which are applicable at the community level. The collected community data should be kept in the data bank.

If necessary and if possible, additional operations using FINERG should be investigated and developed. Specifically, a systematic way to change a linear programming matrix should be generated if some parameters are required to be changed. This will substantially reduce computer time required for an alternative run after an optimal feasible solution has been obtained. The report format of FINERG should be investigated and developed to provide convenience in analyzing results.

Further analysis of the 2 selected communities in this study should be conducted. Perhaps additional communities in different regions should be selected for model testing if funds are available.

Recommendations made by the Consulting Team on the development strategies for the 2 selected communities should be used as the guideline in formulating development plans for communities.

LIST OF TABLES

Table	*Title*	*page*
3.1	Sources and Products Included in Energy Supply Sector	64
3.2	Households Energy Consumption, National, 1980. Annual Per Capita	72
3.3	Rural Household Energy Demands	73
3.4	Energy Demanded for Land Preparation	74
3.5	Energy Demanded for Water Pumping (Mcal/rai)	75
3.6	Energy Demands for Other Agricultural Machinery	76
3.7	Average 1981 Crop Yields	77
3.8	1981 Energy Demand and Crop Production Statistics	78
3.9	Crop Residue and Energy per Unit of Product (Mcal/ton)	79
3.10	Crops by Annual and 5-year Growth Rate	80
3.11	Energy Use for Land Preparation	83
3.12	Energy Use for Water Pumping	84
3.13	Energy Use for Agricultural Machinery	85
3.14	Survey Results on Dung Production	96
3.15	Charcoal Kiln Parameters	98
3.16	Ministry of Communications' TMIS Road Transport Information	113
3.17	Ministry of Communications' TMIS Rail Transport Information	114
3.18	Ministry of Communications' TMIS Inland Waterways and Coastal Transport Information	115
3.19	Ministry of Communications' TMIS Air Transport Information	116
3.20	Ministry of Communications' TMIS International Transport Information	116

LIST OF FIGURES

Figure	*Title*	*page*
	Relationship Among Models and Submodels of the Energy Master Plan Model	3
1.1	Possible Elements of Rural Energy Planning	29
1.2	Farm/Village Energy Related Resource Flows and Transformation	30
3.1	Original Rural Subsystem	56
3.2	Rural Provincial Passenger Transport Demand	58
3.3	Motorcycle Demand (including Rural Demand)	59
3.4	Freight Transport (Rural and Urban)	65
3.5	Rural Household Demand Sector	66
3.6	Rural Agricultural Demand: Example of One Crop	67
3.7	Rural Agricultural Fuel Choice	68
3.8	Othrsup 2: Fuelwood, Charcoal, Residues and Dung	70
3.9	Othrsup 2: Other Supply Sources	71
3.10	Othrsup 3: Other Supply Sources	90
3.11	Othrsup 2: Urban Demands on Other Supply Sources	91
3.12	Transport 1 Scenario	103
3.13	Schematic Diagram for Modified Transportation Submodel	109
3.14	Electricity Scenario	119
3.15	Electricity Scenario	120
3.16	Electricity Scenario	121
3.17	Electricity Scenario	122
3.18	Textile Scenario	123
3.19	Industry Subsystem Flow Diagram	128
3.20	Paper Scenario	129
3.21	Non-metal Scenario	130
3.22	Food & Beverage Scenario	131
3.23	Chemical Scenario	132
3.24	Other Con Scenario	133
3.25	Industry Subsystems	134
3.26	Housetert Flow Diagram	139

Chapter 1
Introduction

INTRODUCTION

This report summarizes three pioneering studies involving sectoral energy planning models developed in Thailand. It explains how a sectoral planning model is built to be operated both independently and as part of a macro model. The models discussed are the Rural Energy Use Model, Submodels of the Energy Master Plan, the Household Energy Model and the Rural Community Development Model.

Chapter 1 provides background on the history of the EMP, energy-economic planning, project objectives and scopes of work. Chapter 2 reviews the EMP model and the Baseline Survey--the works most relevant to the study. Chapter 3 details the work done on the Energy Master Plan submodels (including the Rural Energy Use Model, the Transportation Submodel, the Electricity Submodel, the Textile Industry Submodel, the Paper Industry Submodel and the Urban Household and its Tertiary Submodel). In Chapter 4, the development and test runs of the Rural Energy Models (The Household Energy Model and the Rural Community Development Model) are explained in terms of parameters and test cases. A discussion of results is presented in Chapter 5 and Chapters 6 and 7 are devoted to conclusions and recommendations.

A. HISTORICAL BACKGROUND OF THE ENERGY MASTER PLAN

In order to cope with energy problems in Thailand in a detailed, systematic and comprehensive manner, two important studies were undertaken--the Energy Master Plan of Thailand (EMP) and the Renewable Nonconventional Energy Project.

The Energy Master Plan of Thailand (EMP) was commissioned in 1980 under the sponsorship of the Asian Development Bank (ADB) and The United Nations Development Program (UNDP). The major objective was to equip the National Energy Administration (NEA) with tools to do macro-energy planning and to prepare a long-range, sector-wide energy plan for Thailand "with a view to reducing the growing dependence of energy supply on the import of petroleum products and devising and implementing effective, appropriate measures for improved management of energy demand".

The Renewable Nonconventional Energy Project was commissioned in 1980 under the sponsorship of U.S. Agency for International Development (USAID). The major objectives were to assist the Royal Thai Government (RTG) to work toward reducing importing energy resources, arresting environmental degradation due to deforestation, and creating increased income opportunities in rural areas. This was to be carried out through:

Previous Page Blank

- Developing RTG institutional capacity to perform and sustain energy policy planning;

- Introducing and testing renewable energy technologies in rural areas; and

- Developing and testing techniques for disseminating such technologies.

In essence, Thailand's Renewable Nonconventional Energy project has two reinforcing components: institutional development and the testing, adaptation and dissemination of renewable energy technologies relating to rural needs.

This report is a part of the Energy Master Plan Support Component of Thailand's Renewable Nonconventional Energy Project. It summarizes the following studies:

(1) Meta Systems Inc, Energy Master Plan Component Renewable Nonconventional Energy Project,
Vol. I. Rural Energy Planning
Vol. II. Rural Energy Use Model
Vol. III. Village Energy Model

(2) T. Raengkhum and P. Somboonpanya, Development of EMP submodel.

(3) T. Raengkhum, P. Somboonpanya, A. Wattanankit and P. Pornchaiwiseskul, Rural Community Development Model.

These three studies can be separated into two main groups. One group contains The Energy Master Plan Submodels (EMPS) concerned with augmentation and improvement of the EMP submodels. The EMP Submodels include the Rural Energy Use Model and the EMP submodels. The other group contains the Rural Energy Models which include the Household Energy Model (HEM) and the Rural Community Development Model (RCDM).

These two groups of studies were designed to be supporting and supplementing activities for the EMP study, to help develop RTG institutional capacity to perform and sustain energy policy planning. Particular emphasis is also given to rural energy planning.

B. ENERGY - ECONOMIC PLANNING

General

Systematic and comprehensive energy-economic planning generally considers and covers three levels of planning; macro-energy planning (or an energy master plan), sectoral energy planning and energy project planning. Among the various levels of planning, consistency is needed to ensure that plans at various levels complement each other and all parts of the plan are feasible and implementable.

The EMP is essentially a macro energy planning tool. It addresses all major energy areas in the macro framework of energy-economy interaction. A large number of issues are considered. The important ones are:

- Investment decisions;
- Pricing policy;
- Resource development;
- Technology R & D in the energy sector; and
- Balance of payments considerations.

The EMP model is an integrated model that combines all energy related subsystems. A large model such as this leads to complexity of construction, operation, analysis and interpretation. Moreover, limitations of computer software and hardware (in addition to data availability) produced a certain subsystem simplicity. That is, the subsystems of the EMP were not detailed and comprehensive enough for sectoral energy planning.

One solution was to improve the level of detail in the subsystems of the existing EMP at the cost of complexity of operation, analysis and interpretation of the model. The other was to build sectoral planning models that could be analyzed independently, separately from and still consistently with the EMP so that construction, operation, interpretation and understanding of a particular subsystem of the EMP could be achieved easily. Both solutions can be achieved depending on data availability, time limitations and art of modeling.

Energy project planning normally deals with a specific project. The feasibility of an energy project needs to be addressed because investment in an energy project is always large and requires a significant national investment.

The Energy Master Plan Submodel (EMPS) and the Rural Energy Models are essentially sectoral energy planning models designed to augment the existing EMP and evolve a plan that is detailed and comprehensive enough for sectoral planning. As mentioned earlier, particular emphasis is also given to rural energy planning. Therefore details of rural energy planning are expounded in the next section.

Rural Energy Planning

Rural energy planning is discussed below in terms the overall rural planning process, specific energy flows, planning and rural energy systems.

The Overall Rural Planning Process

The design of a rural energy planning effort should be based on a review and analysis of information pertaining to the physical, agricultural and socio-economic systems with which rural energy systems are interlinked.

The overall rural planning process is presented diagramatically in Fig. 1.1. The initial phase, shown on the extreme left, involves a review of existing data. Information from these reviews flows to a synthesizing effort and establishes the dimensions and design for the planning efforts shown in the center of the figure. This synthesis effort occurs before any further data collection and/or analysis. If the data on existing conventional energy systems are combined with information from institutions dealing with energy, agriculture and rural developemnt problems, it is generally possible to divide the country into regions for rural energy planning in much the same way as has been done for other development activities.

The analysis of rural energy systems is, of course, directly influenced by decisions made concerning overall agriculture (including forestry) and industrial sector development as well as by macroeconomic policy decisions; this linkage is show schematically in Fig. 1.2. The rectangles represent study elements which are primarily concerned with descriptive efforts, either data collection or engineering descriptions. The circles represent tasks that include formal analysis and modeling activities.

As Figure 1.2 shows, the results of various energy use studies, along with information on the future from the macroeconomic, agriculture, forestry, and industrial sector planning efforts, are brought into an analysis of future demands. More specifically, future levels of economic activity (such as production of rice versus cassava or other crops) are estimated. It is from these projected levels of economic activity that the derived demand for various energy needs (fertilizer, pumping, traction, shaft power, etc.) can be estimated. The resulting energy need projections are brought together with the results of the various supply studies in studies of representative subsystems (household/community).

The model was used as a macro-analytic tool to facilitate these system studies. Such a model is an extension of approaches regularly used by agricultural economists and planners. A more aggregate methodology was used in the rural component of the existing EMP. This model used a sector level analysis similar to that shown schematically in the right-hand portion of Figure 1.2.

Specific Energy Flows

As Figure 1.2 shows, there are many important energy flows into crop production and multiple flows from crop production to the remainder of the household or community economy. Thus, agricultural activities are both source and sink of energy flows. In some situations, particularly in poor

Figure 1.1

Possible Elements of Rural Energy Planning

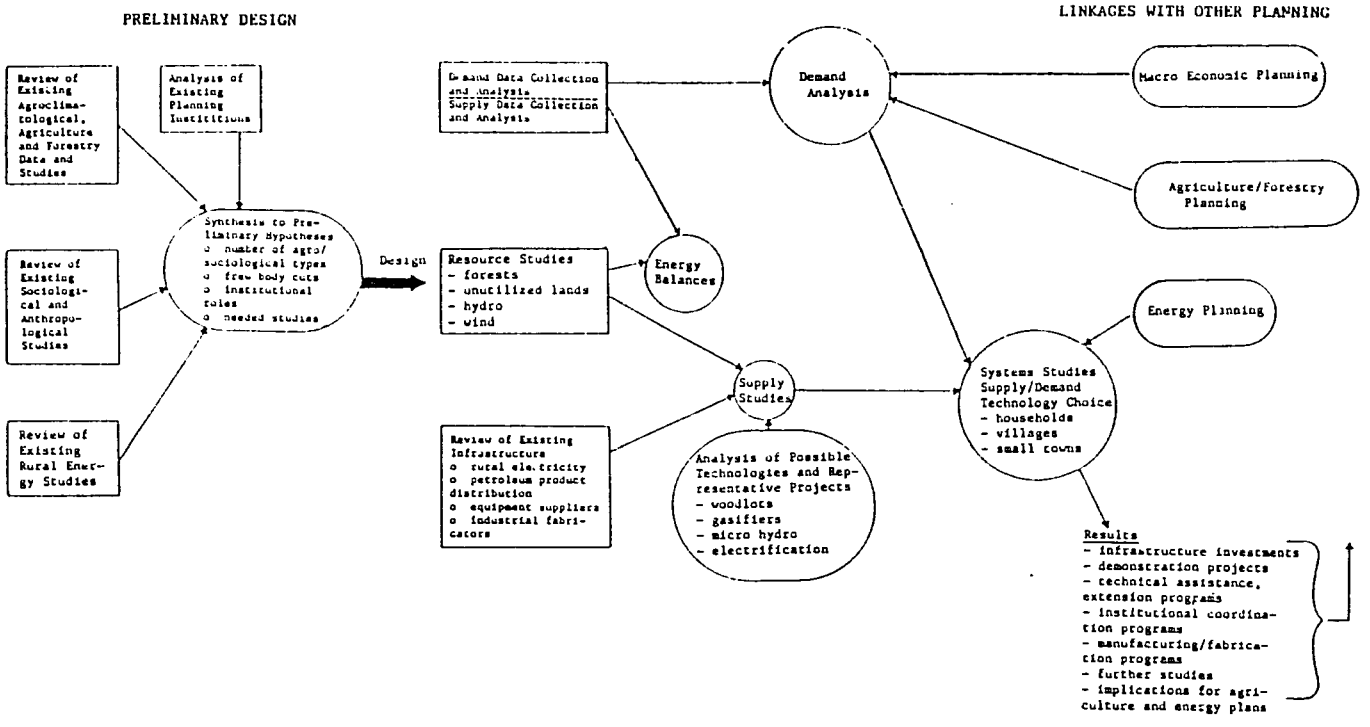
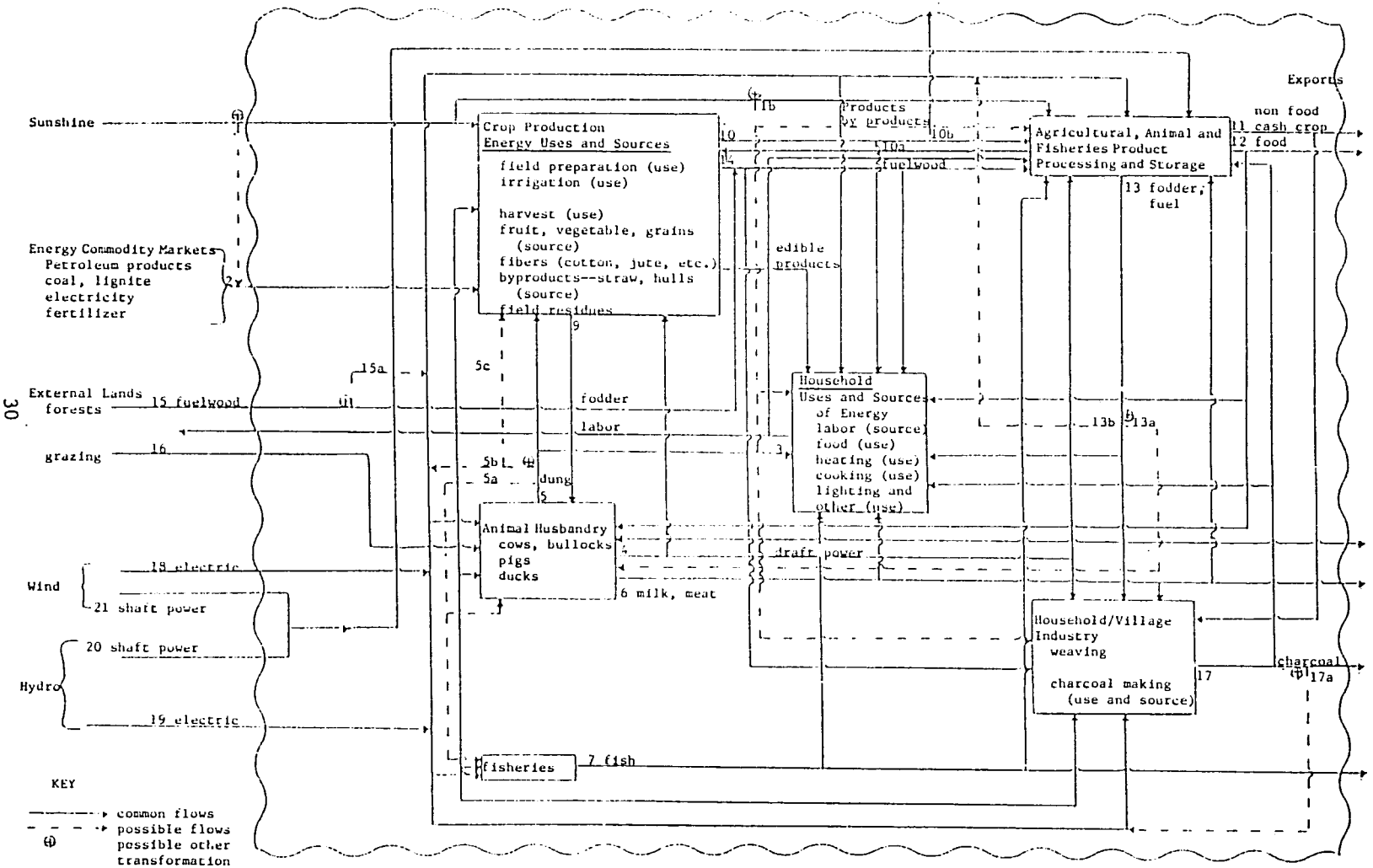


Fig. 1.2 Farm/Village Energy Related Resource Flows and Transformation



areas of Asia and Africa, these activities are precariously balanced at a subsistence level; change in any energy flow will affect crops, livestock and household activities. In other situations where the system is less tightly balanced, changes in energy flow can have little system wide impact. Some of the potentially important flows and their interactions with other activities are numbered in Figure 1.2 to facilitate the discussion.

Most activities are dependent on solar energy (flow 1). Its flow can be considered constant from year to year but exhibits seasonal and diurnal variation. The usual flow patterns are to all photosynthetic activities and to "patio drying" for a wide spectrum of crops including cassava and rice. New solar energy collection and transformation technologies include flat plate and concentrating collectors for space or water heating, solar crop dryers, and even solar cookers. The possible resulting flows (1b) are shown as broken lines in Figure 1.2. These possible transformations are not widespread in any developing country at this time. Another solar energy--technology being demonstrated/used is photovoltaics--the direct conversion of sunlight to electricity. This possible flow (1a) is shown joining the conventional energy flows (2).

Many farm household or community activities are dependent on the flow of commercial energy commodities from outside markets. These flows are presented as a single aggregate flow (2). This flow is meant to represent any external source or transformation of an external source e.g., kerosene for lighting, gasoline and/or diesel for mobile or stationary shaft power production, electricity from autogeneration as well as fertilizer and other petrochemical-based inputs and purchased electricity. In some cases these commercial sources represent only a fraction of the annual energy balance since the principal sources are animate and inanimate sources from within the village system.

There are two energy flows--labor and livestock. Most household labor (flow 3) is utilized in crop production, livestock husbandry, crop-processing activities and, in some communities, fisheries. Household activities and rural industry also use labor. In addition, there are other activities (such as fuelwood gathering) that take labor flows from outside the system boundary. These labor flows can vary significantly with season, particularly as a function of cropland preparation and crop-processing. Where the labor supply is limited, shifts to more energy-intensive agriculture may not be possible unless labor productivity can be raised through mechanization which requires new or altered flows, or unless labor is freed from competing uses such as fuelwood collection.

The other animate energy source is draft animals. This flow (4) is common in most, but not all, rural societies. In Thailand, there is considerable variation. Some provinces rely heavily on tractors while others use buffalos and cows as the main source of traction power. For the latter, a reduction in draft animal numbers can hinder crop production and processing unless the draft power is replaced by mechanization. While an increase in the number of draft animals can increase agricultural productivity, improved technologies for mechanical to mechanical conversions, such as better collars, plows or pump drives, are alternatives that have had some application and should be considered.

Animals are critical energy conversion devices in both traditional and modern rural energy systems. They convert fodder energy flows to mechanical power, food, fuel and fertilizer (dung). This last output is shown schematically as flow 5 in Figure 1.2. This flow is a major source of nutrients for crop production in many traditional systems. In parts of the world where firewood or other energy sources are scarce or too expensive, the dung is a major source of domestic fuel. As dung use for fuel increases in situations of tight fuel supplies, its use as a fertilizer must decrease, and crop production may suffer unless other sources of nutrients (such as commercial fertilizers) are provided. This has not yet been the case in Thailand, but has happened elsewhere in Asia. The flow of commercial fertilizer is common in many areas, but the quantity will vary from very small (under traditional production techniques to much higher (under "modern" techniques).

There are a number of possible (but less common) flows that are variations or transformations of the flow of animal wastes. One is the flow (5a) common to parts of Asia in which animal waste (and in some cases human waste) is used as a nutrient in fish and/or duck ponds. A potential transformation and subsequent flow is biogas production based on dung. This flow (5b) has been tried in Thailand and other countries with mixed success. Although the low BTU gas produced in biogas does not have the energy density to allow extensive transport within or between villages, this gas can be a substitute for commercial fuels in heat, light and shaft power end uses. For the sake of simplicity, it is presented as a flow entering the flow of commercial energy commodities rather than in terms of all the potential different flows which could stem from a biogas plant. The biogas process also has a slurry by-product that can be used as fertilizer.

Other energy products of animal husbandry such milk, eggs and meat (flow 6) are usually consumed in households or sold (exported) to markets outside the village (or household). In some cases, however, they can be the basis for rural industry such as curd making. Food energy products also flow from fishery activities (flow 7). Generally they go to the household although, in many circumstances, they will be exported either before or after some processing (e.g., drying) and storage.

There are a number of distinct energy flows from agricultural production. The first are those food energy products (such as vegetables) which can go directly (flow 8) to household use without processing. Other unprocessed products may provide fodder energy flows to animal husbandry (flow 9) (such as crop-field residues) which are grazed by animals. Other agricultural products or by-products are available after minimal processing, e.g., threshing (flow 10). These generally include food and fiber products and by-products. Some by-products, such as rubber trees felled during replanting, may be used as a household fuel (flow 10a), while others are exported directly without processing (flow 10b).

The energy-related flows stemming from processing and storage are of three broad categories. One is the non-food flow that includes "cash crop" products such as fibers (cotton, jute, tobacco, and fruits) (flow 11) which are either exported or used in household/village industries. Another flow (12) from processing and storage includes food products such as milled grains, cassava or red sugar which are either exported or used in

households. The third important flow (13) from processing or storage activities includes by-products or waste products (rice hulls, bran, straw, bagasse, .etc.) which have potential energy values as fuel or fodder. These flows can go to the household, to animal husbandry or to exported markets. An example is rice bran going to a large piggery. Less common flows are to village industry such as the use of rice hulls in traditional charcoal-making in some regions of Thailand. Another such flow utilizes technologies, ranging from simple to more sophisticated, which increase the digestability of waste and by-products, thus producing a higher-value fodder energy (flow 13a). Another potential flow is as a fuel in external combustion engines (steam, sterling engines) that produce shaft power or electricity, or to gasifiers and/or controlled combustion units that are coupled with heat producing technologies (burners, boilers, etc.) or to internal combustion engines. For simplicity, these potential flows (flow 13b) are shown schematically as merging with flow 2 to indicate that they are possible substitutes for such conventional energy commodities as coal, petroleum products and electricity.

The principal energy source in the energy budgets of most rural households and communities is fuelwood. There are generally two sources of fuelwood. The first is from within the village--woodlots or household trees, etc. From this source it flows (14) mainly to household users, to crop processing (e.g., tobacco curing), rural industry (either to be burned directly or to be used as a feedstock for charcoal making), or to market for export. The other source of fuelwood is forests or other lands outside of the village boundary. This flow (15) is shown as merging with the other fuelwood flow. Fuelwood can be transformed by using technologies such as steam engines, gasification, etc. to produce electricity or gas. This potential flow (15a) is also shown as merging with that of the commercial flows for which it may substitute. In certain cases, there may be other important sources either external or internal to the systems. Increasing attention is being given to organizing the production of fuelwood in rural areas either within the household or village boundary on marginal or less production lands as well as along roads, etc., or outside the village or household boundaries.

Fodder can be obtained from outside the household or village boundary by animals grazing on grasses and browse, or by villagers gathering fodder sources (leaves, grasses, etc.) and transporting them to the animals (flow 16).

Small hydro sources provide shaft power (flow 20) through relatively simple mechanical mechanisms (e.g., water wheels) in many areas endowed with hydro potential. In areas with wind potential, simple wind machines are used as the sources of shaft power (flow 2). In the case of wind, the flows usually go into water pumping and in the case of hydro, to crop processing activities such as milling. Both sources are also being used as sources for farm or community-scale electric power generation. These flows are merged with the conventional energy flows (2), for which they act as substitutes.

In many areas, charcoal-making is a rural industry. The feedstocks are fuelwood and/or residues, and the technologies range from earth pits to more efficient kilns. The charcoal energy flows (17) generally go to

households and crop processing, but can also go to export markets. There is also the potential to use charcoal in gasifier-equipped, internal combustion engines.

The EMP Rural Energy Use Model, which is discussed in Chapter 3 allows a more explicit description of the rural energy flows, transformations and end uses, than in the national EMP structure. This is especially true for biomass-based sources. An initial data set was estimated from existing information on demand-supply balance in rural areas. Revision of these national estimates can follow if analyses with the household and community energy models suggest how these aggregate rural demand-supply balances will shift. Aggregate estimates should be developed after using the Household and Community models on a number of representative cases.

In the Household and Community Energy Models discussed in Chapter 4, a methodology is presented which allows the explicit analysis of the sources, energy flows and technology options discussed above. The various energy sources differ based on their qualities (such as food, fodder and fuel). This methodology analyzes the tradeoffs of using these sources for competing acitivities with or without the introduction of new technologies, as well as the options of using conventional energy sources with different technologies. The tradeoffs can be evaluated in terms of measures relevant to the household or community, e.g. cost minimization, or revenue maximization, food or fuel self-sufficiency, etc.

The analysis at the household and community levels should reflect a number of important characteristics of household and community energy systems which either explicitly or implicitly affect the choices of energy supply flows and technology options and, hence, demand-supply balances. Among these characteristics are the differences in access to energy resources and implicit and explicit supply costs.

In low-income areas, the choice of sources is often driven primarily by the availability of free or low-cost (except collection time) sources. However, such sources are not equally available. The problems of unequal distribution and/or access to energy resources are not well documented or understood. The better known aspects of these problems are the broader problems of inequalities in regional resource balances or conventional infrastructure. The inequalities of regional resource availability cases include situations in which fuelwood availability varies markedly from country to country and within a country. The difference in fuelwood availability can be quite dramatic as can be seen by comparing the Northeast, especially Srisaket, with the North, especially the hills around Chiang Mai. The differences are usually a function of high population density relative to natural and/or managed land productivity. The availability of competitive fuels can also impact this variation. In some provinces, rice husks are sold as fuel, but in other provinces of Thailand these husks are piled high outside the mills and available to all for the cost of transport.

Unequal access to conventional energy infrastructure obviously affects the choice of sources. If the supply is physically not available (or only available at some inconvenience and/or high cost) these sources will not be used. The relative access also affects the price and/or reliability. For

example, petroleum products may have higher prices in the rural area due to high transport costs, lack of competition, or unreliability of supply. Conversion or end-use technologies whose effective operation costs are dependent on access to spares and maintenance can also be affected.

The choice of sources is also determined by the implicit cost associated with the labor or other inputs needed for gathering or utilizing traditional fuels. In rural energy systems, fuel switching, factor substitution and conversion take place as a result of the relative or absolute changes in the implicit price of supplies of traditional or conventional energy commodities. The changes are analogous to those found in modern urban/industrial energy systems, but the rural consumers' choice is constrained by the imperfections of their marketplace (information, capital, organization) and/or their resource endowment and technology status.

Changes in supply price (implicit or explicit increases) can also occur when a technology is introduced that leads to a new and different demand-supply balance. Formerly, larger farmers who owned cattle regarded dung as a valueless commodity and the poor and landless were free to collect and use it. Under the new equilibrium, less dung is freely available, and the price shift primarily affects the poor who can least afford it. The shift can also be caused by factors outside the rural system. In some areas of Costa Rica, scrap wood at rural saw mills was formerly available for the cost of collection or, at most, a very minimal charge. However, with some agro-industry and other users now switching from oil to wood-fired burners and boilers, this waste wood has a market value that makes it worthwhile to ship to industrial users.

Other price shifts for suppliers come as a result of action outside the rural area. Most important of these are extensions of the infrastructure for conventional energy which effectively lower the cost of supplies such as electricity, kerosene or diesel fuel. The introduction of electricity in rural electrification programs effectively lowers the cost of electricity but only for the wealthier families who can afford the cost of a hookup and continuing payment.

The prices of conventional energy may also increase--especially with an increase in world prices and/or changes in government policies. This has tended to reduce consumption of conventional energy, increase the use of traditional fuels in some uses such as crop drying, and push up the price of traditional fuels.

Planning Rural Energy Systems

The development of rural energy systems is not a goal in itself. The objective is economic development. Planning for rural energy must therefore go hand in hand with agricultural and rural development planning. There are two dimensions that must be considered in suggesting appropriate mechanisms for rural energy planning. One dimension encompasses the necessary information sources, special studies and analytical procedures that could be used. The second dimension incorporates the institutional structure within which this planning should or could take place. Given the variety of

institutions that deal with the planning responsibilities, it is not possible here to suggest a unique institutional arrangement for dealing with rural energy issues. However, even on information and data issues, cooperation among various agencies is needed in designing information and collection systems.

C. OBJECTIVES OF STUDY

Overall Objectives

The six overall objectives of the three studies are:

1. To strengthen RTG institutional capacity, particularly the NEA, to perform and sustain energy policy planning;

2. To support and supplement activities for the EMP study, particularly in the area of renewable energy relating to rural needs.

3. To equip the NEA with tools to do sectoral energy planning, especially rural energy planning.

4. To develop a Job Control Language (JCL) for the NEA's Remote Job Entry (RJE) terminal in order that data for the EMP could be entered at the NEA's RJE terminal in utilizing the computer at the National Statistical Office (NSO).

5. To improve the rural energy sector in the EMP study by constructing a Rural Energy Use Model to meet the requirements of more comprehensive rural energy planning than was possible on the basis of the existing EMP study. Besides, the model should be operated, analyzed and interpreted separately and independently from and, moreover, consistently with the EMP study. Inclusion of such separate, independent subsystems are also needed in the development of EMP submodels such as transportation, electricity, the textile industry, the paper industry, and the Urban Household and its tertiary subsystem; and

6. To construct the Household Energy Model and the Rural Community Development Model in order to simulate the decision-making process for the best allocation of resources at the micro levels of planning: household and community. Particular emphasis is on rural development and rural energy planning.

Rural Energy Use Model

The principal objectives of the Rural Energy Use Model were:

1. To identify in detail the rural energy components in the existing

EMP model. This includes (a) identifying the existing demand sector nodes, (b) identifying the links to the supply sectors, and (c) identifying the bases of the rural demand projections.

2. To create an expanded rural energy demand sector and an enlarged supply sector based on meeting the requirements of more comprehensive rural energy planning than was possible on the basis of the existing EMP model alone. This includes (a) expanding the demand sectors to allow a more disaggregated understanding of the likely evolution of rural energy demand regarding both the type of energy required and the underlying determinants of growth, (b) enlarging the supply sectors to permit the inclusion of a number of nonconventional, renewable technologies as well as allowing an expanded description of traditional fuels, and (c) devising a suitable link-node structure to interrelate the newly created demand and supply sectors.

3. To obtain preliminary runs of the newly created enlarged rural model using (a) revised projections of demand, and (b) suitable assumptions on implementation rates and costs of new technologies.

4. To identify the critical areas needing further data collection, analysis or policy attention (such as fuelwood shortages).

5. To make recommendations regarding the types and quality of further data to be collected/integrated and the procedures for operating the model.

The EMP Submodels

The prime objectives in the development of the EMP submodels were:

1. To divide the existing integrated system into appropriate separate subsystems in order that subsystems could be understood by people who are familiar with a particular subsystem.

2. To prepare basic, separate subsystems which can be expanded at a later date.

3. To investigate the posibilities of establishing a data bank for the EMP data base as well as those data collection procedures which are necessary for future EMP study.

4. To develop Job Control Language (JCL) for NEA's Remote Job Entry (RJE) terminal so that data for the EMP could be entered at the NEA's RJE terminal using the NSO computer.

The Rural Energy Models: The HEM and the RCDM

Household Energy Model (HEM)

The objective of the HEM was to design and develop a model to simulate the decision-making process of a village household when choosing among different sources of energy, allocating the energy to different activities and selecting the conversion and end-use technologies for these activities.

The resources available to the household are specified by including owned and rented assets as well as community assets available to the household. The different technologies which are incorporated in the model are sized for household use. The demands of the household are determined by the size of the household, including the number of adults and children, the amount of the land and the quantity of animals owned.

Rural Community Development Model (RCDM)

The prime objective of the RCDM study was to develop a model to simulate a decision-making process for rural community development with emphasis on rural energy development, taking into account the income, economic conditions, and occupations of people in typical communities as well as resources (e.g. natural, human, labor) in the communities.

The income of community people was maximized in such a way that resources, labor, and technologies are used in an appropriate manner.

This study applies concepts used in the development of an Energy Master Plan (EMP) model and a Household Energy Model (HEM) to develop a Rural Community Development Model (RCDM) for typical Thai rural communities. The RCDM will be used to simulate the development and usage of energy resources available in the area along with related economic development programs. The model developed will be used to determine optimal development strategies in selecting energy related and other development programs for selected communities. Subsequently, energy technologies required for community development could be evaluated and determined.

The RCDM was also designed to meet the following objectives:

1. To extend the HEM to include detailed energy supply and demand in submodels as well as to incorporate development programs on a community scale into the model;

2. To develop optimal criteria to conform with national objectives; and.

3. To modify the HEM to include a time scale for required planning intervals.

D. SIGNIFICANCE OF THE STUDIES

Overall Significance

These models will strengthen the NEA to perform and sustain effective energy policy planning. Particularly in rural energy planning, energy strategies can be planned in a more detailed and comprehensive manner such that acceleration of rural development, improvement of rural life and better income distribution (which are prime objectives in Thailand's fifth five year development plan 1982-1986) can be achieved successfully.

Moreover, the models will equip the NEA with tools for sectoral as well as macro-energy planning. It is easier to construct, operate, analyze and interpret sectoral models than the EMP as a whole. Therefore,

coordination with agencies on a particular subsystem or sectoral subsystem, survey design and data collection, can be done more effectively.

Rural Energy Use Model

The Rural Energy Use Model was designed to provide NEA with a framework for rural energy use which:

- Follows the same analytical structure as the EMP (and uses the same software);

- Can be run completely separately from the main model or in a "weakly linked" mode;

- Has provision for a much larger data base in the rural sector than currently exists to provide indicators for future data collection activities;

- Has provision for a more detailed and comprehensive demand projection methodology than existed in the original model; and

- Has an expanded data base and structure for those new resource and conversion technologies that are especially relevant to the rural energy sector in Thailand.

The EMP Submodels

The development of EMP submodels will provide NEA with:

- An effective means to discuss the development of appropriate subsystems with concerned persons or agencies;

- Opportunities to add nodes/links (which could not be included in the large integrated model) that will provide a better means to determine appropriate parameters to be used for the large, integrated system in obtaining global optimization.

- A better idea about how to collect the necessary data/information to establish a data bank for the future EMP data base.

- An opportunity to use NEA's RJE terminal to access the NSO computer, if the nescessary software and hardware are available.

Household Energy Model (HEM)

As a decision-making model, the HEM will determine what activities the household will undertake and what resources it will use. Each activity is described in terms of its requirement for complementary inputs, e.g. land, fertilizer, water, and labor for growing a crop. The allocation of the resources and selection of technologies to perform different activities are based on maximizing net income, subject to the constraints relating to minimum requirements to meet household requirements.

Rural Community Development Model (RCDM)

As National Income (GNP less Depreciation) is an indicator of national progress, community income is one of the best macro-economic indicators of the progress of communities. Accordingly, a linear programming model has been developed to maximize the income of a selected community under study within given end-products/services goals and resource constraints.

The model provides an excellent means to evaluate the impact of the introduction of new energy technologies to communities. For example, value of residuals will be increased when they are converted to energy, employing the new energy technologies introduced.

E. SCOPE OF WORK

The scope of work for the EMP project primarily involved its updating and redesign, based on the development and integration of revised models and submodels. Thus, since the scope of work for the EMP model was interrelated to the development of the Rural Energy Use Model, the EMP Submodels, and the Rural Energy Models, their individual scopes of work are presented below.

Rural Energy Use Model

The scope of work the Rural Energy Use Model covered:

- A review of the EMP subsystem model for rural energy use.

- Undertaking studies of analytical methodologies and models which could improve the structure of planning and policy analysis to deal with rural energy problems in the future.

- Using the analytical approach of the EMP model to construct an expanded rural sector which would permit a more detailed and disaggregated picture of rural energy flows as well as allow some evaluation of the trade-offs in introducing new energy technologies which would be difficult to do within the more aggregate model.

- Providing a focus for enhanced data collection activities and permitting a detailed periodic accounting of rural energy supply-demand flows at the national level.

The EMP Submodels

The scope of work for submodel development included:

- A Review of the EMP model to evaluate concepts and weaknesses, and to detail information for proposed submodel development, including the investigation of the uses of parameters,data, etc. in the existing EMP model.

- Submodel Development. This includes:

  (a) Evaluation of the existing subsystems included in the EMP model. The evaluation is made based on factors such as:

  - complexity and how it contributes to the integrated model,

  - potential of the expansions required for future analysis of the subsystems,

  - importance to national energy planning,

  - degree of accuracy required in the estimation of parameters used in the integrated EMP model.

  (b) Setting up the priorities for submodelling based on the evaluation of each sub-system. Upon a mutual agreement between NEA and the Study Team, a number of subsystems are selected for further development within the available time frame.

  (c) Conducting detailed studies on the subsystems selected. This includes the study of appropriate demand and supply nodes of the selected subsystems, and appropriate ways of separating the subsystems.

  (d) Developing flow diagrams for the selected subsystems. The flow diagrams are used as a part of the documentation for this study as well as for future submodel expansions to be recommended.

  (e) Developing independent submodels for the selected subsystems. This involves the modifications, as necessary, of the input data of the FINERG software for each submodel for the selected subsystem.

- Implementation.

The subsystems developed are run to test workability of the software developed. Further modifications are made, when necessary.

When sub-optimization results are obtained, they are analysed by comparing them to the global optimization results of the integrated EMP model.

- Recommendations for Future Development.

Potential expansion of submodels for the selected subsystems are investigated and recommendations for future development are made based on factors such as their importance to national energy planning and the degree of accuracy required in the estimation of parameters used in the integrated EMP.

Investigation of the possibilities of establishing an EMP data base for selected subsystems are conducted. Recommendations are made taking

into account the appropriate sources of data/information, appropriate means in estimations of parameters, and the degree of accuracy required.

- Development of Remote Job Entry Capability.

This task is conducted separately from other tasks to provide NEA with a capability to use the available RJE terminal for entering EMP data at NEA to be processed at NSO's data processing center. The task includes:

(a) Investigation of hardware and software available at NSO and NEA.

(b) Development of Job Control Language (JCL) for the NEA's RJE terminal for the EMP run.

The Rural Energy Models: the Household Energy Model (HEM) and the Rural Community Development Model (RCDM)

The scope of work for the Household Energy Model involved:

- Analyzing household activity relationships to represent rural household characteristics by dividing household activities into major components;

- Determining model coefficients and values of parameters to reflect household conditions;

- Using a matrix generating program to perform functions to generate output for input into a linear programming model for the optimization results;

- Performing test runs employing prototypical data from selected households and conducting sensitivity analysis.

The scope of work for the Rural Community Development model involved the:

- Development of a compatible planning energy supply model to HEM and expansion or modification of the model to include a time scale for required planning intervals. The energy supply model takes into account alternative energy resources, energy conversion or distribution processes so that the model can be used to evaluate community scale energy projects.

- Development of a compatible linkage between the HEM model and national objectives. The criteria of optimality is that the HEM be in accordance with the statement of national objectives.

- Integration of the model into a computer run process. The submodel is computerized and integrated with the HEM for both a test run and production run.

Chapter 2

Review of the Energy Master Plan Model and the Baseline Energy Survey

REVIEW OF THE ENERGY MASTER PLAN MODEL AND THE BASELINE ENERGY SURVEY

The works most relevant to this study are two documents--The Development of an Energy Master Plan Model (EMP) and the Baseline Energy Survey. A brief overview of the contents of each is presented here.

A. THE ENERGY MASTER PLAN MODEL (EMP)

The five basic components (or tools) of the Energy Master Plan are listed below. They are:

1. An Energy Reference System (ERS) description of the Thai energy sector, including all major supply alternatives, conversion processes, and major components of the energy-consuming subsystems of the economy;

2. An associated energy sector data base;

3. Energy sector simulation and optimization software designed to operate on the basis of the ERS and associated data bases;

4. A set of linkage relations used in forecasting demands for the energy sector simulation and optimization models, which are designed to accept as inputs the outputs of either the NESDB macroeconomic forecasting model or an adaptation of that model;

5. A macroeconomic forecasting model adapted from one in use at the NESDB in conjunction with the formulation and revision of macroeconomic development plans.

The Energy Reference System (ERS)

The energy reference system for Thailand is composed of 15 major subsystems which are integrated into a single unified system for simulation and optimization purposes. There are five supply subsystems, one conversion subsystem, and nine demand subsystems in the unified model, as follows:

Supply subsystems

1. Solid fossil fuels (lignite, coal, oil shale)

2. Natural gas

Previous Page Blank

3. Oil and Petroleum products

4. Hydropower and geothermal energy

5. Other Supply

- wood fuels
- bagasse
- rice husk
- biogas
- ethanol
- urban refuse
- solar energy
- wind power
- nuclear fuel

Conversion subsystems

1. Electricity generation, transmission and distribution.

Final demand subsystems

1. Chemical industries
2. Food and beverage industries
3. Nonmetallic industries
4. Paper industry
5. Textile industry
6. Other industry
7. Transportation
8. Urban households and tertiary sector
9. Rural households and agriculture

The Energy Sector Data Base

The energy data base contains a massive amount of both historical and projected data relating to these subsystems and the specific activities represented within them. Such information includes import and export prices, reserve estimates, installed capacities, investment and operating costs, process yields, conversion efficiencies, operating characteristics (such as electrical load parameters), historical and projected production levels, and so forth.

In the EMP studies, projections were prepared for 5 snapshot years covering a 20-year planning period. The energy sector simulation and optimization models developed for the EMP were designed to simulate and/or optimize over this planning period as a whole, starting from input data describing the configuration of the energy sector in Thailand for the "base" year. The base year serves as a benchmark and calibration point for the operations of the models.

The data base itself contains historical information on such key items as installed capacities, reserves, prices, and investment costs etc. Projections for future snapshot years were prepared on the basis of the historical data available.

The Simulation Software

Simulation enables the use of the model and data base as a large calculating machine. It permits calculations of the "if. . . then" variety, but is entirely dependent on input data determining the choice among fuels, processes, or utilization alternatives represented in the model. It can be used to calculate energy flows, balances, and costs resulting from such predetermined decisions, but provides no real insights as to the value of the trade-offs which might be involved or as to the "most desirable" among the large number of possible future development alternatives open for the Thai energy sector.

The Optimization Software

Optimization modelling is designed to evaluate systematically each of the possible alternatives and find the "most desirable" one according to the criteria selected for optimization, (given a full set of data describing the various options open for the development of the energy sector, and their costs, yields, and efficiencies, as well as any external constraints affecting their development).

The optimization model generates estimates of the "value" of each alternative in contributing to the achievement of the desired objective in the form of estimates of the degree to which marginal deviations from the optimal solution would affect the increments to the present value of energy supply cost over the plan period for each supply alternative. This information provides important insights about the magnitude of the trade-offs involved in selecting alternative development paths.

The optimization model also provides valuable information on the way

in which the configuration of the "most desirable" development path will change in response to important changes in the planning data or assumptions. Thus, various scenarios can be constructed to reflect changes in assumed values for such key parameters as reserves, import prices, investment costs, and demand growth, thereby enabling estimation of the impact of such changes on various components of the energy development plan. The stability of the most likely scenarios--the base cases--can be checked, and key sensitivities identitied.

The Macroeconomic Forecasting Model

Using NESDB forcasts of such selected macroeconomic variables as input, equations were estimated to forecast the output levels of the various energy-consuming processes represented in the EMP optimization model. Equations were estimated linking such things as cement, glass, and paper output to appropriate variables contained in the NESDB model.

The EMP modeling system is fully integrated from economic activity to end-use sectors, to primary supply. A change in any variable such as price, cost, or resource availability anywhere in the system will result in changes throughout the system, often in ways that would be difficult to anticipate, much less measure, in the absence of such a modelling framework. A change in the projected composition of GDP, for example, will have a distinct impact on the composition and overall growth rate of final energy demand, which in turn will change the entire configuration of capacity and associated investment requirements for energy sector development.

E. BASE LINE ENERGY SURVEY

The Base Line Energy Survey was conducted in 1981 by Meta Systems Inc. and Thai Group Co., Ltd. The results from the survey provide general data on village activities and energy use as well as basic research data to be used for the Renewable Nonconventional Energy Project. The survey was conducted by interviewing 1,900 households in 50 villages in 10 provinces. The survey activities included:

- Household Questionnaire;
- Informal Interviews;
- Land Use Inventory;
- Charcoal Making Observations;
- Stove Tests;
- Biomass Sample Collection;
- Dung Collection;
- Forest Survey;
- Field Residue Survey;
- Photographic Documentation;
- Rural Industry Survey;

- Appropriate Technologies;
- Energy Seller; and
- Short Census.

The results of the survey were presented in 14 one-volume reports as follows:

1. Survey: The Overview and a Guide to Data
2. Biomass samples : Collection and analysis
3. Trees : Production, uses and needs
4. Stoves : Experiments and cooking observations
5. Charcoal : Kiln experiments
6. Rural Industry : Survey results
7. Additional Data: Technology selection, appropriate Technology, energy sellers
8. Household survey : Socio-economic Data
9. Household survey : Domestic fuel sources and uses cooking, lighting, heating
10. Household survey : Agricultural and livestock data
11. Household survey : Community development, health, water supply and transport
12. Household survey : Thai and English Questionnairs
13. Household survey : Programmer's guide for research data
14. Base maps : Nation, Changwat, Villages

Chapter 3

Energy Master Plan Submodels (EMPS)

Previous Page Blank

ENERGY MASTER PLAN SUBMODELS (EMPS)

A. ENERGY MASTER PLAN SUBMODELS UNDER STUDY

As was mentioned in Chapter 2, there are five supply subsystems, one conversion subsystem and nine demand subsystems in the EMP model. This subsystem breakdown was used throughout the EMP model study.

To meet the requirements of more comprehensive rural energy planning than was possible using the existing EMP, the present Rural Energy Use Model was based on an augmented rural energy demand sector and an enlarged supply sector. It was developed to more adequately deal with rural energy matters at the macro level.

"For the Development of the EMP submodel" study, only the Transportation subsystem, the Electricity subsystem, the Textile subsystem, the Paper Industry Subsystem and the Urban Household and its Tertiary subsystem were considered.

Techniques and Procedures for Developing Data Bases

The simplest way to build submodels that can be run completely separately from the EMP model or in a weakly linked mode, is to extract the selected subsystem from the EMP model. Additional links can then be added to improve the details of the subsystem considered. It should be noted that relevant 'ANCILLARY' and 'BY-PRODUCT' parameters must also be included in the subsystem considered. This is handled by creating supply nodes for the relevant 'ANCILLARY' parameter and demand nodes for the relevant 'BY-PRODUCT' parameter. Any node number that is not used can be assigned. In the Development of the EMP submodels, node '000' and '999' are assigned as supply nodes for the relevant 'ANCILLARY' parameter and as demand nodes for the relevant 'BY-PRODUCT' parameter respectively.

An ANCILLARY parameter allows the FINERG software to connect flows in processes to the point where the flow has to be produced. A BY-PRODUCT parameter allows the FINERG software to connect the generated by-products to the processes where they are used.

Next, the upstream nodes of the subsystem considered are linked to any node that is not used (or node '000'). Appropriate, purchased or shadow prices from the EMP optimization results would be assigned to the link. On the final downstream nodes of the subsystem considered, which would otherwise connect with oter nodes of EMP mode, the flows must be assigned.

For the submodel testing, to be consistent with the EMP, the shadow prices and flows mentioned above should come from EMP optimization results.

It should also be noted that additional links for improvement of the

Previous Page Blank

details of the subsystem considered are dependent on data availability, art of model construction and computer software/hardware limitations.

Having completed the process as outlined above the submodel is built. It then can be run not only in conjunction with but also completely separately and independently from the EMP model, or in a weakly linked mode.

In the following sections, the Energy Use Model will be discussed along with the development of EMP submodels based on the Transportation subsystem, the Electricity subsystem, the Textile subsystem, the Paper Industry subsystem and the Urban Household and its Tertiary subsystem.

All these subsystems were improved and input in a computer data base and can be used as independent subsystems.

Results from test runs have been satisfactory. All the computer data base records of each subsystem were collected using (and according to) FINERG software for EMP modeling (see FINERG Data Collection Handbook). The computer data bases are available at the NEA or through the Rural Energy Use Model Study and the Development of EMP Submodels study. They are therefore not discussed in detail in this report.

A Submodel's Usefulness and Potential Application

A submodel built according to the techniques and procedures mentioned above is very useful and has many potential applications. Thai is:

- The submodel can be run not only in conjunction with but also completely separately and independently from the EMP Model, or in a weakly linked mode. This will save a lot of computer time. Moreover, a submodel can be improved more easily than the whole EMP model because computer software has enough room for submodel detailing.

- The submodel can be explained, understood and interpreted and analyzed more easily than the whole EMP model. Yet the results are consistent with the whole EMP model at the macro level.

- Data base design and collection can be easily implemented for each subsystem. Cooperation from various agencies can be requested and responsibilities assigned easily. Agencies concerned with information in a given submodel quickly understand the need of data collection in their own endeavor and thus, the communication gap can be reduced.

- Improvement, interpretation, understanding, analysis and data collection of each subsystem can be done quickly at low cost (including computer cost) because each subsystem can be worked out independently and separately from the whole EMP model. The scale of work is much reduced.

B. THE RURAL ENERGY USE MODEL

Analysis of existing EMP Model.

The rural sector in the original EMP model has two major demand sub-sectors, rural households and agriculture. Rural households have 2 activity demand nodes, cooking and lighting. Agriculture consists of 3 activity demand nodes: tractors, water pumping and agricultural machinery. These are aggregated across all crops.

In addition, the EMP model includes sugar milling and rice milling as demand nodes under the food and beverage sub-sector of the industrial sector. The existing link structure of these demand nodes to the supply side includes the bagasse and rice husks produced as by-products of cane and paddy production and used for steam raising/electricity generation in sugar and rice mills.

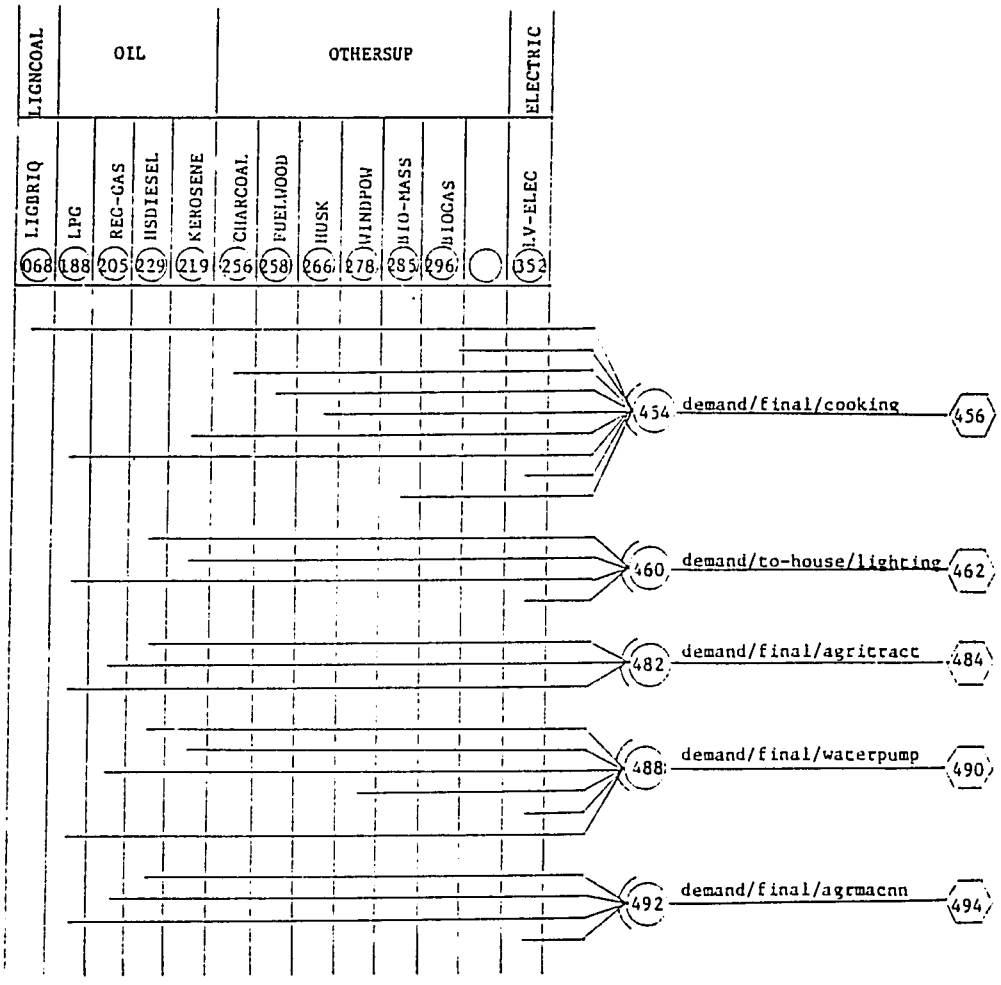
Fig 3.1 shows the original base year (1977) networks from supply to demand for rural households and agricultural production in the EMP model. Only the following connections between activities and fuels are used:

Cooking:	Firewood Charcoal Paddy husk LPG Electricity
Lighting:	Kerosene Electricity Diesel LPG
Agricultural production: (including tractor, water pumping agricultural machinery)	Premium gasoline Regular gasoline High-speed diesel LPG Electricity

For future years, the structure of the EMP model allows for links to a larger number of sources and converted fuel forms, including lignite briquettes for cooking, biogas for cooking, biomass (it is not clearly explained what this refers to), and wind power for water pumping (presumably mechanical).

The rural sector in the original model does not break out rural industry or rural transport. As stated above, sugar milling and rice milling, which can be considered as agricultural processing industries in the rural sector, are included in the industrial sector; the other crop processing activities as well as other rural industries are neglected. Rural transport is aggregated with all other urban and inter-urban transport.

Fig. 3.1 Original Rural Subsystem



The Revised Rural Energy Use Model

Based on the considerations outlined in the objectives of this task, i.e., to provide a more comprehensive representation of rural energy flows and to incorporate a number of new technologies, a completely new and revised rural demand and supply sector with additional, appropriate links was created.

An overall description of the supply, conversion and demand sectors and the activity subsectors considered for inclusion in the revised EMP model is presented below.

The Rural Energy Use Model is composed of rural energy demand sectors including subsector network links (see Figs. 3.2 and 3.3).

The Rural Energy Demand Sector

The rural energy demand sector has four major components for rural areas: rural households, agricultural production, rural industry and rural transport.

Rural Household

The main activity subsectors in the rural household demand sector are as follows:

- Cooking;
- Lighting;
- Ironing;
- Household industry;
- Space heating;
- Fumigation;
- Miscellaneous appliances (electrical); and
- Water pumping (for household use).

The choice of these sub-sectors was based entirely on the information collected in the rural energy survey carried out by the NEA in 1980. Since data by fuel type are available for each of these sub-sectors on a national basis, it was decided to incorporate this disaggregation into the model.

Agricultural Production

For the agricultural production component, the following main activity sub-sectors were indentified for each crop grown.

- Land Preparation: This includes the activities such as ploughing, tilling, weeding, etc., necessary to prepare the land for the production of crops. The type of energy embodied here is mechanical energy from mobile machinery, e.g. tractors, or from animate sources (animals and human labor).

Fig. 3.2 Rural Provincial Passenger Transport Demand

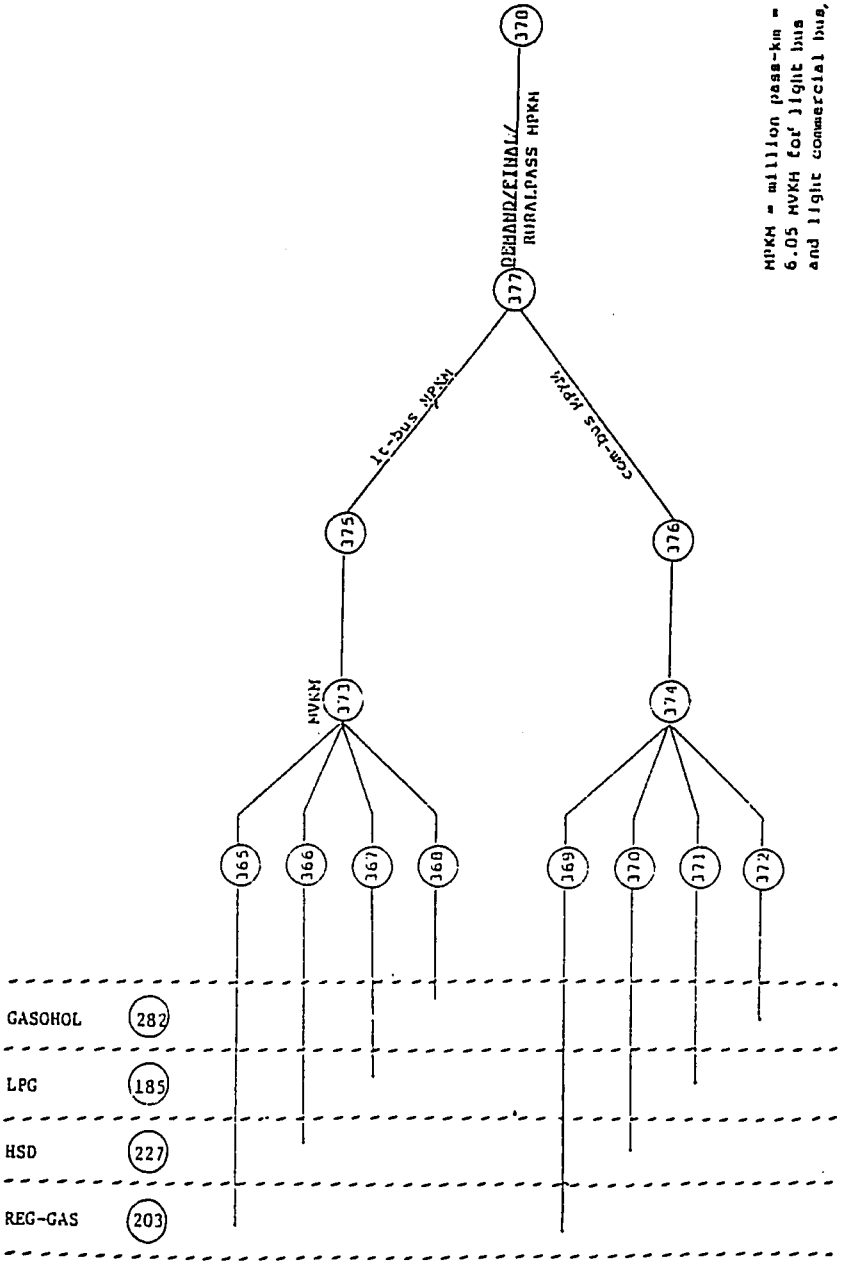
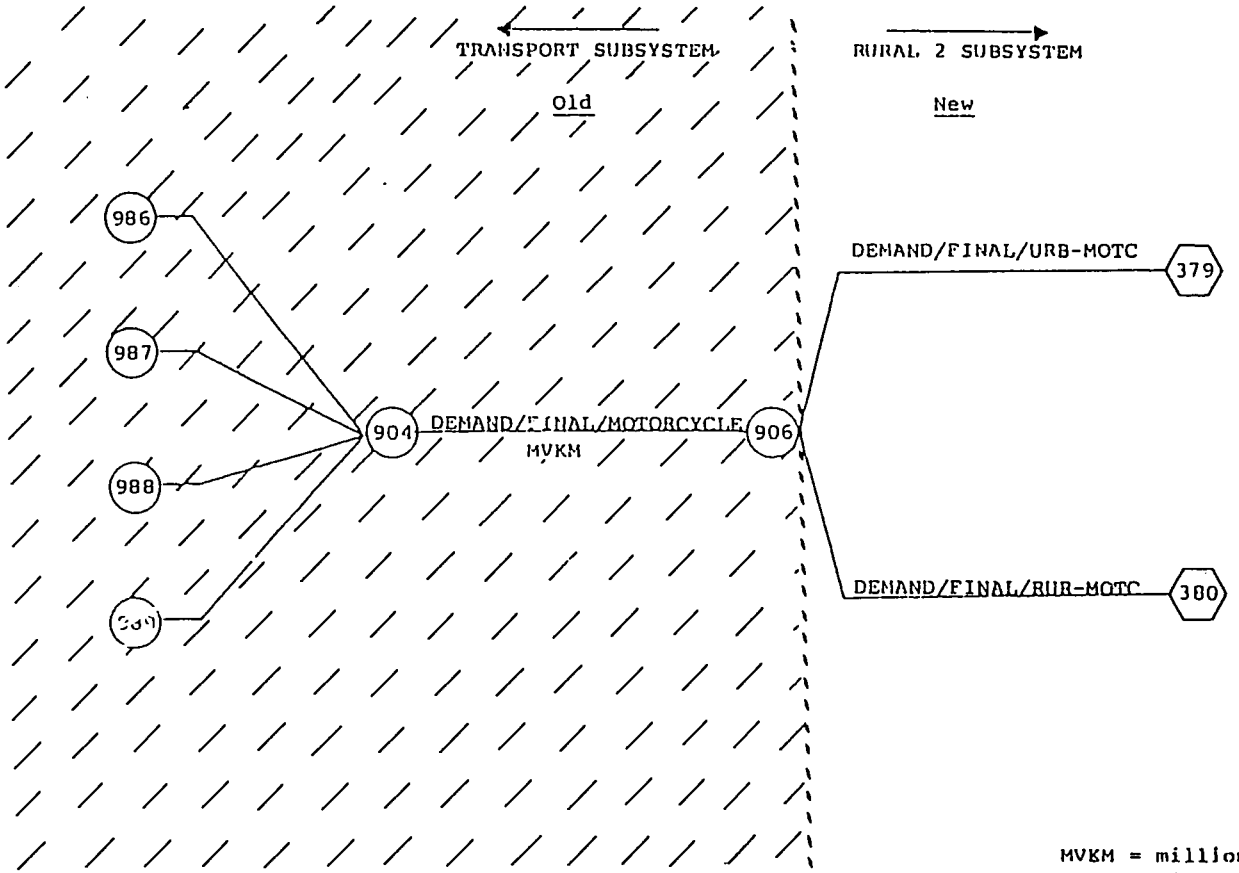


Fig. 3.3 Motorcycle Demand (Including Rural Demand)



MVKM = million vehicle kilometers

- Water Pumping: This includes the energy requirements of lifting water from underground or surface sources for crop irrigation.

- Fertilization: This includes the energy equivalent of nutrients (fertilizers) required for plant growth; these come from either chemical fertilizers or organic manures.

- Harvesting/Threshing and other agricultural operations: This includes the mobile and stationary mechanical energy requirements of harvesting the crop and of other agricultural operations.

The above activity sub-sectors have been designated for each of the seven major agricultural products as follows:

1. Rice (first crop)
2. Rice (second crop)
3. Cassava
4. Sugar
5. Corn
6. Beans
7. Rubber
8. Other

Data is available from the NEA Rural Survey (1980) on the fuels consumed by tractors (mainly for land preparation), irrigation pumps, and other agricultural mechinery. In addition, data on the number of animal-days and human labor-days spent for each crop are available.

Rural Industry

The selection of main activity sub-sectors under rural industry poses severe difficulties, largely due to the lack of disaggregated data in this area. The data base of the existing EMP model includes consumption figures on an aggregated national level for several industries, parts of which are located in rural areas. Some isolated data are available from the NEA (1980) Survey and the Meta Systems Survey, but there are considerable problems in extrapolating the small sample results to the national level. The objective of sector definition in rural industry should be to include small-scale, low technology types of industries which would probably not be accounted for in the larger industry sector. Additionally, it should also include units engaged in the processing or pre-processing of agricultural raw materials such as rice milling, tobacco drying, sugar processing, etc. The problem of sub-sector disaggregation, particularly where boundaries tend to overlap, is a difficult one, and the only solution is careful and consistent data collection and analysis.

Preliminary indentification of which rural industry activity sub-sectors should be included in the EMP rural sector is as follows:

- Non-Agro-industry

  Small-scale brick manufacture

Limestone kilns
Small-scale ceramics manufacture
Small-scale ice manufacture
Small-scale metal working
Small lumber operations
Small-scale textile manufacture
Farm equipment repair

- Agro-industry

Small-scale rice milling
Tobacco curing
Small-scale sugar processing
Cassava processing
Rubber processing

The existing EMP demand sector data base and link structure include data and links on a number of these activities. For example, in the agricultural processing industries, sugar processing and rice milling (presumably large-scale) are included, and in the non-agricultural industries, ceramics, metal working, ice manufacture and textiles are included. However, while sugar and rice processing can be easily included within rural industry, the rural component of non-agricultural industries needs to be suitably broken out from the aggregate totals in the current data base. There does not exist any meaningful way of doing this at the present time.

It should be noted that there is no available survey data from which national totals of energy consumption in rural industry can be derived. The survey carried out by Meta Systems in the Non-Conventional Renewable Energy Project on rural industry provides a great deal of useful information directly relevant to this area, but the sample size of 47 establishments is too limited to permit any meaningful extrapolation to a national total.

Rural Transport

The rural transport sector suffers from some of the same difficulties as the rural industry sector. The existing EMP model data base incorporates aggregate national totals for various types of modes (auto, truck, bus, railway, etc.) and uses (passenger/freight), part of which arise within the rural sector but are not separately identified as such.

The existing EMP structure for the (final) transportation energy demand sector consists of 11 nodes as follows:

Node no.	Description	Unit of Measurement
935	International waterborne	TCAL
927	Fishery	TCAL
939	Domestic aviation	TCAL
941	International aviation	TCAL
902	Passenger cars	MVKM (million vehicle-km)
930	Metropolitan passenger	MPKM (million passenger-km)

911	Interurban passenger	MPKM
942	Other urban passenger	MPKM
906	Motorcycle	MVKM
923	Overland freight	MTKM (million freight-ton km)
931	Coastal and inland waterborne	TCAL

No distinction between rural and urban sectors in the existing EMP model is made for the above categories.

A closer examination of the detailed structure of those nodes which could potentially arise from rural demand reveals some inconsistencies in the existing EMP model. The first 7 nodes in the above list (935-911) do not have relevance to the rural sector, so we do not deal with them here.

The next 3 nodes, i.e. 942, 906 and 923, do have relevance to the rural sector. Their structure is as follows:

Node	Description	Modes	Unit
942	Other urban passenger	City Bus, Taxi	MPKM
906	Motorcycle	Motorcycle	MVKM
923	Overland freight	Rail, Heavy Truck, Light Truck	MTKM

Node 942, which is designated in the input as Other Urban Passenger and includes only city bus and taxi modes, is projected in the existing model by the rural population growth rate. This appears inconsistent and contradictory. Our guess is that this refers to Provincial Passengers, part of which includes rural passenger transport. Furthermore, rural passengers are very unlikely to use taxis considering their purchasing power. On the other hand, there is much more likely use of light buses or light commercial buses (pick-up type) for rural passenger transport. Thus, we have changed the nodes and utilization characteristics of this node as follows.

Node 942 now refers to Provincial Passengers, which includes both Other Urban and Rural Passenger transport. In addition, the node now includes private cars and taxis, heavy buses, and light buses or light commercial (LC) buses. The basic information to derive the current and forecasted MPKM in this category has come from "Studies of Energy Policy for the Transport Sector" carried out for the Ministry of Transport by BCEOM in 1981.

The revised link-node diagram for this category is now show in Fig. 3.2. The node 942 has been split into two nodes, one of which refers to other urban passengers and the other to rural passenger alone. The other passenger node has links with all four modes, car-taxi, LC bus, light bus and heavy bus, while the rural passenger node has links only with LC bus and light bus.

The rural motorcycle (passenger) transport has been explicitly incorporated by splitting up the original activity node into two nodes, one for rural and the other for urban. Data from the BCEOM study on the amount of motorcycle vehicle-kilometers utilized on national, provincial and rural

roads were used to break out the aggregate totals in the EMP model into urban and rural motorcycle demand.

A similar procedure was carried out for freight transport where the BCEOM study contained breakdown by mode (light truck, 6-wheel truck, 10-wheel truck and railway) for national, provincial and rural roads (and railroads).

Figs. 3.3 and 3.4 show the link-node structure constructed for motorcycle passenger transport and freight transport.

Rural Energy Supply Sector

The rural energy supply sectors considered for the rural model have been divided into three categories:

Conventional
Traditional
Non-Conventional

The different sources and products included in these categories are shown in Table 3.1

Supply-Conversion Sectors

The various supply sources are not just used directly but through a number of converted fuel forms. The most important of these traditionally for the rural sector is charcoal, which is the major cooking fuel. Charcoal can be produced from any of the four types of wood that we have defined earlier or from residues (rice straw). Charcoal has 3 kiln types, two of which are built where the wood/residue is gathered and one which is a permanent kiln. All kiln types can produce household charcoal for rural families (outside of the monetary economy); however, only the permanent kilns produce charcoal which is commercially traded.

Other converted fuel forms introduced in the model are as follows:

Converted Fuel	Source(s)
Biogas	Animal Dung Agricultural Residue
Producer Gas	Wood Agricultural Residue
Ethanol	Sugarcane Cassava
Decentralized electricity	Biogas Producer Gas

Sub-Sector Network Links

Figs. 3.5 through 3.7 show the network structure of links and nodes from the fuel to the final demand sectors for the remaining 2 major sub-sectors of rural energy demand, i.e., household and agricultural

Table 3.1 Sources and Products Included in Energy Supply Sector

Sources and Products Included in Energy Supply Sector

Source	Products
Conventional:	
Petroleum	High-Speed Diesel
	Low-Speed Diesel
	Regular Gasoline
	Premium Gasoline
	LPG
	Kerosene
Lignite	
Electricity	Grid-supplied
Traditional:	
Fuelwood	Fuelwood 1 (near village)
	Fuelwood 2 (medium distance)
	Fuelwood 3 (far distance)
	Fuelwood 4 (tree plantation)
Agricultural Residues 1/	Bagasse
	Rice husk
	Rice straw
	Cassava residue
	Corn cobs
	Other
Animal Dung 2/	Animal Dung 1 (Buffalo)
	Animal Dung 2 (Cow)
	Animal Dung 3 (Swine)
Animate Energy	Human labor
	Animal labor
Non-Conventional:	
Solar	Solar Thermal
	Solar Photovoltaic
Wind	Wind Mechanical
	Wind Electric
Mini/Micro Hydro	Decentralized (LV) electricity

1/ Residues are divided into two groups: on-site and field, depending on whether they are used at the site or transported. Bagasse and husk a.e treated separately from the other residues since they are extensively used in commercial processing industries.

2/ It should be noted that use of animal dung for direct energy uses will be a new source in Thailand. We have included it in the traditional sources since it is widely used as a fertilizer, which we have defined as one of the (indirect) energy needs in agricultural production.

Fig. 3.4 Freight Transport (Rural and Urban)

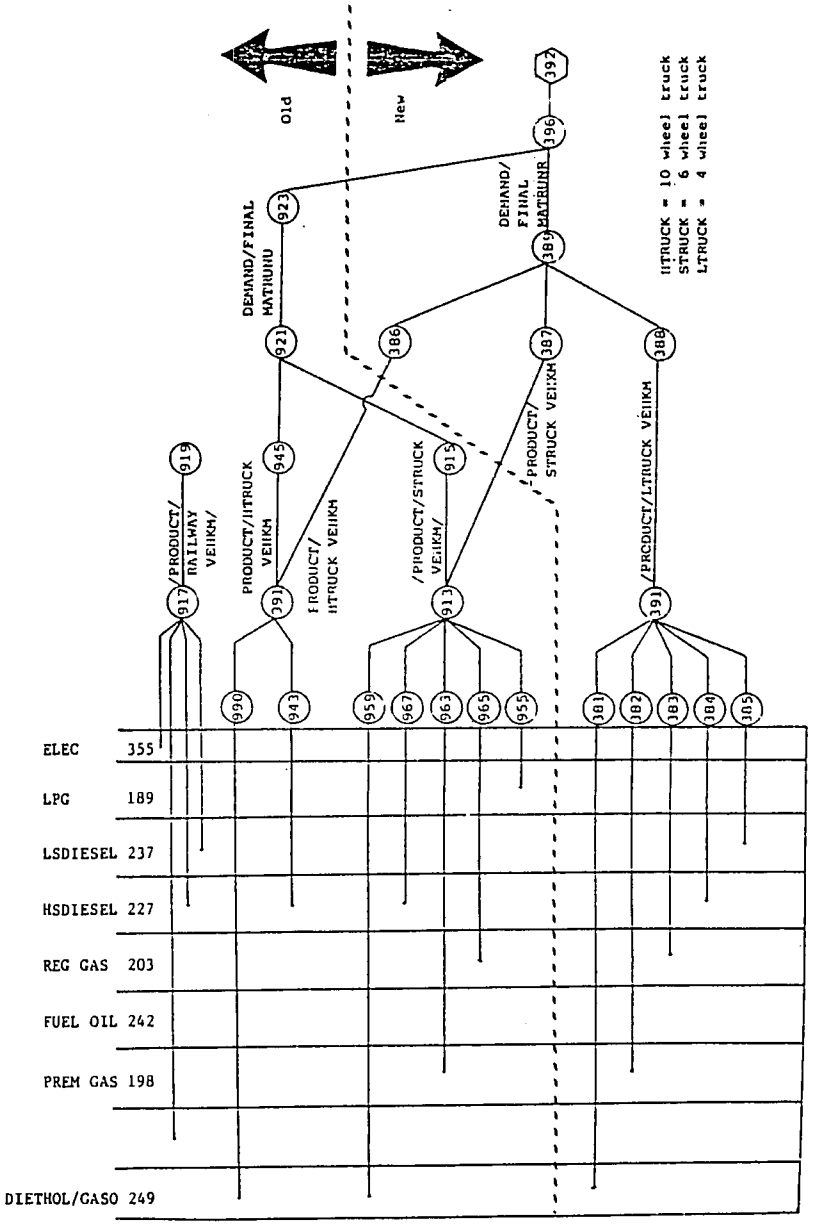


Fig. 3.5 Rural Household Demand Sector

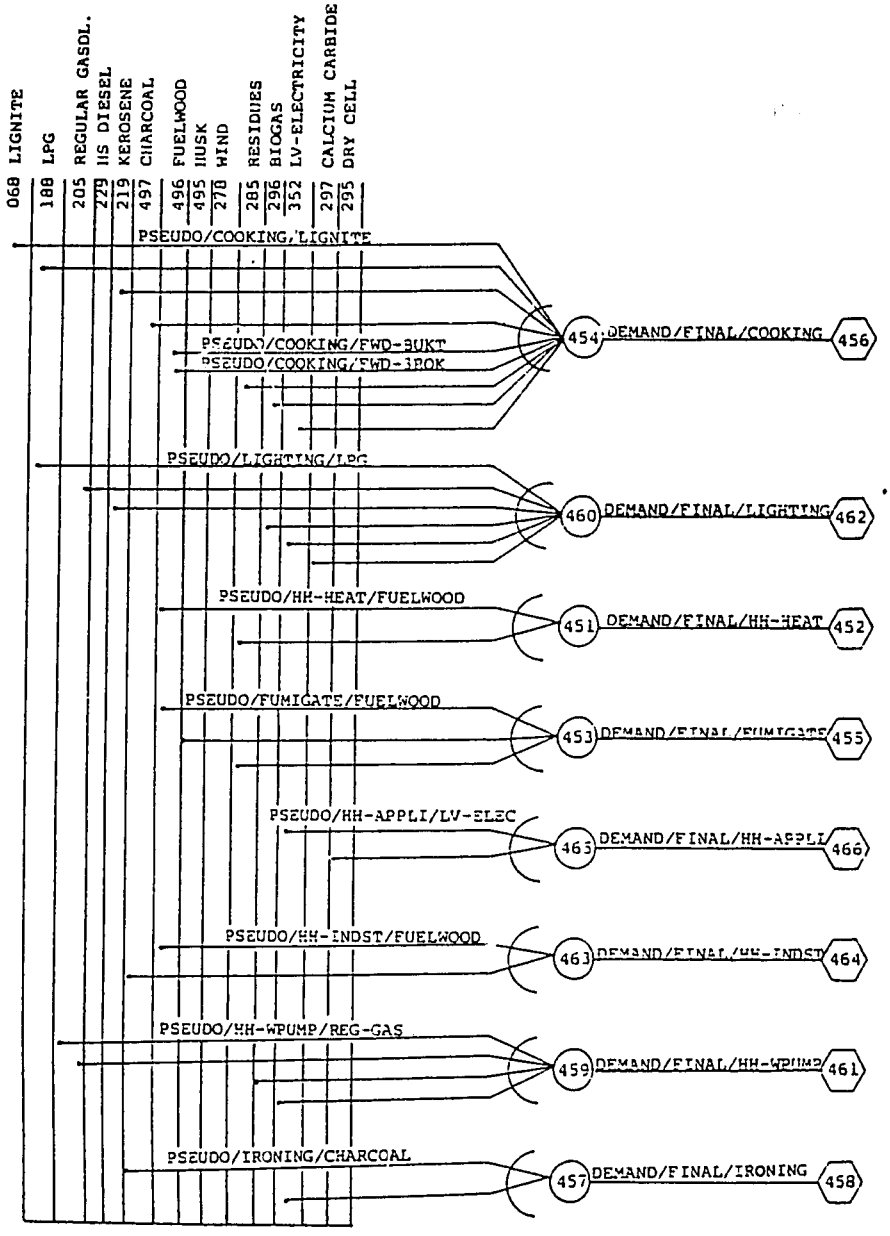
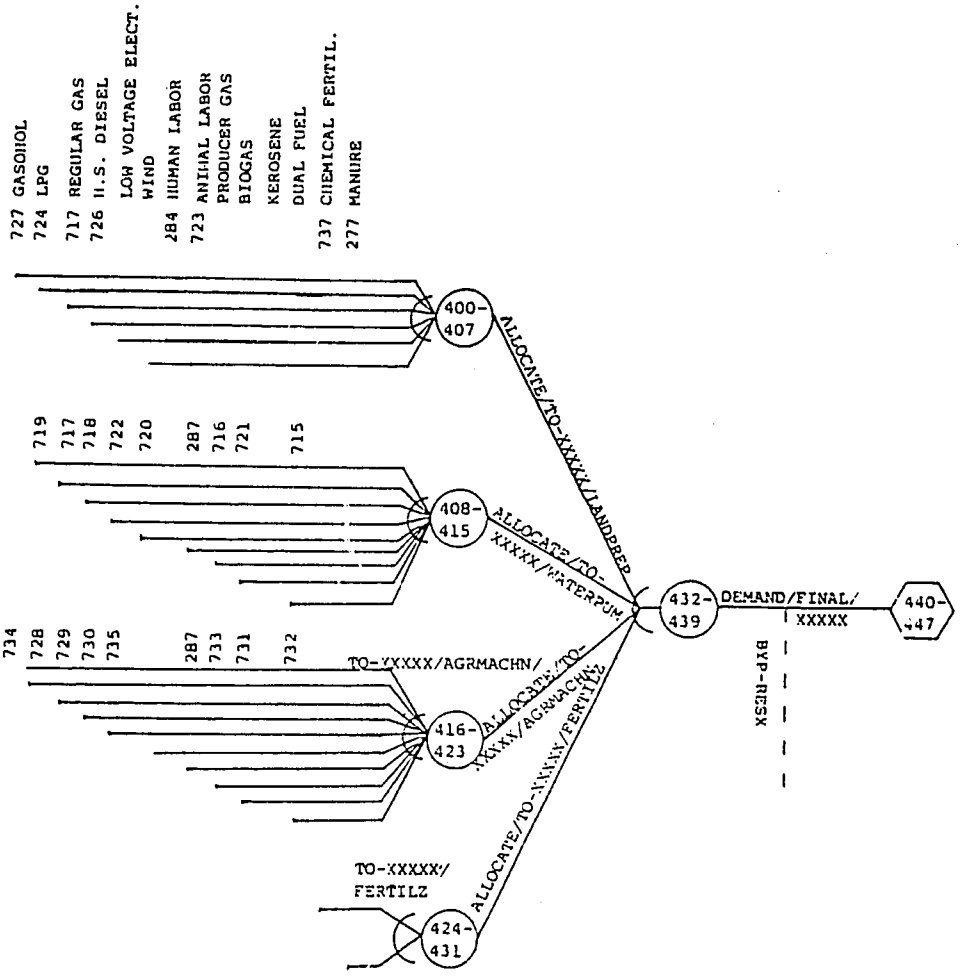
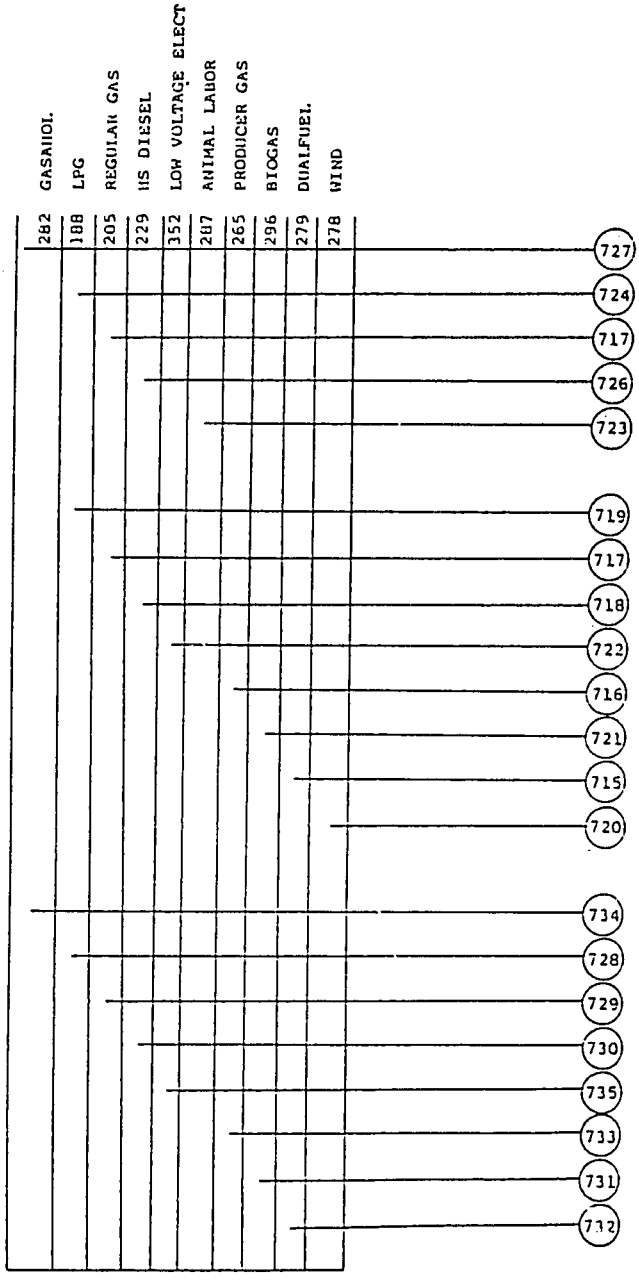


Fig. 3.6 Rural Agricultural Demand: Example of One Crop



This network is repeated for first rice, second rice, maize, rubber, cassava, beans, sugar and all other crops. The node number sequences shown above relate to these eight crop groups, respectively. Each crop has at least one byproduct residue produced in the final "DEMAND" link.

Fig. 3.7 Rural Agricultural Fuel Choice



production. (The rural transport network figures have been presented in an earlier section, and the rural industry sector was not analyzed in this study due to lack of basic data.)

Figs 3.8 through 3.9 show the links from the different supply sources to the nodes of the converted fuel forms.

Data Base for Rural Energy Use Model

Households

The base year (1981) energy consumption data for rural household demand come from the NEA Survey referred to earlier. While the survey provides useful national totals in a rough, "first-cut" sense, a number of improvements in this data base are necessary before it can be used for more definitive planning exercises. These are discussed at more length in a later section.

The NEA rural household energy use data is presented in its original form as Table 3.2. In order to adapt this data to the form used in the rural sector model (Table 3.3), it was supplemented with information from other sources. The final form is consistent with the link-node network shown in Fig. 3.5. The additional information is as follows:

- Rural population (historical and forecasted);
- Energy conversion efficiency of each fuel used for each activity;
- Identification of potential new fuels and conversion technologies for each activity;
- Forecasts of the market penetration of each new fuel for each purpose;
- Forecasts of per capita energy intensity for each purpose; and
- Cost of converting fuels for a specific activity (this was estimated only for water pumping).

Historical rural population estimates were prepared for a 1981 memorandum to the EMP Study Team by Techapun Raengkhum and Supot Tadyu. Rural population forecasts were provided in the same document. The baseline and projected rural population numbers are:

1981	1986	1991	1996	2001
32.881	34.842	35.842	36.315	36.839

The energy conversion efficiency of each of these for fuel use in the rural household is indicated in the model. The conversion efficiency is included as a characteristic of the device. The bucket-type charcoal stoves sampled in the Meta Systems Rural Survey showed a mean conversion efficiency of 22%. This mean value was entered into the model as the efficiency of converting charcoal energy into cooking energy. Since two types of wood stoves were examined and they were found to have different fuel efficiencies; both types, the 3-rock and bucket type, are represented in the model. Most of the other conversion efficiencies are far cruder, and in some cases a default value of 1.0 was used. When the default value of 1.0 is used, the allocation of the fuel cannot be interpreted as having a

Fig. 3.8 Othrsup 2: Fuelwood, Charcoal, Residues and Dung

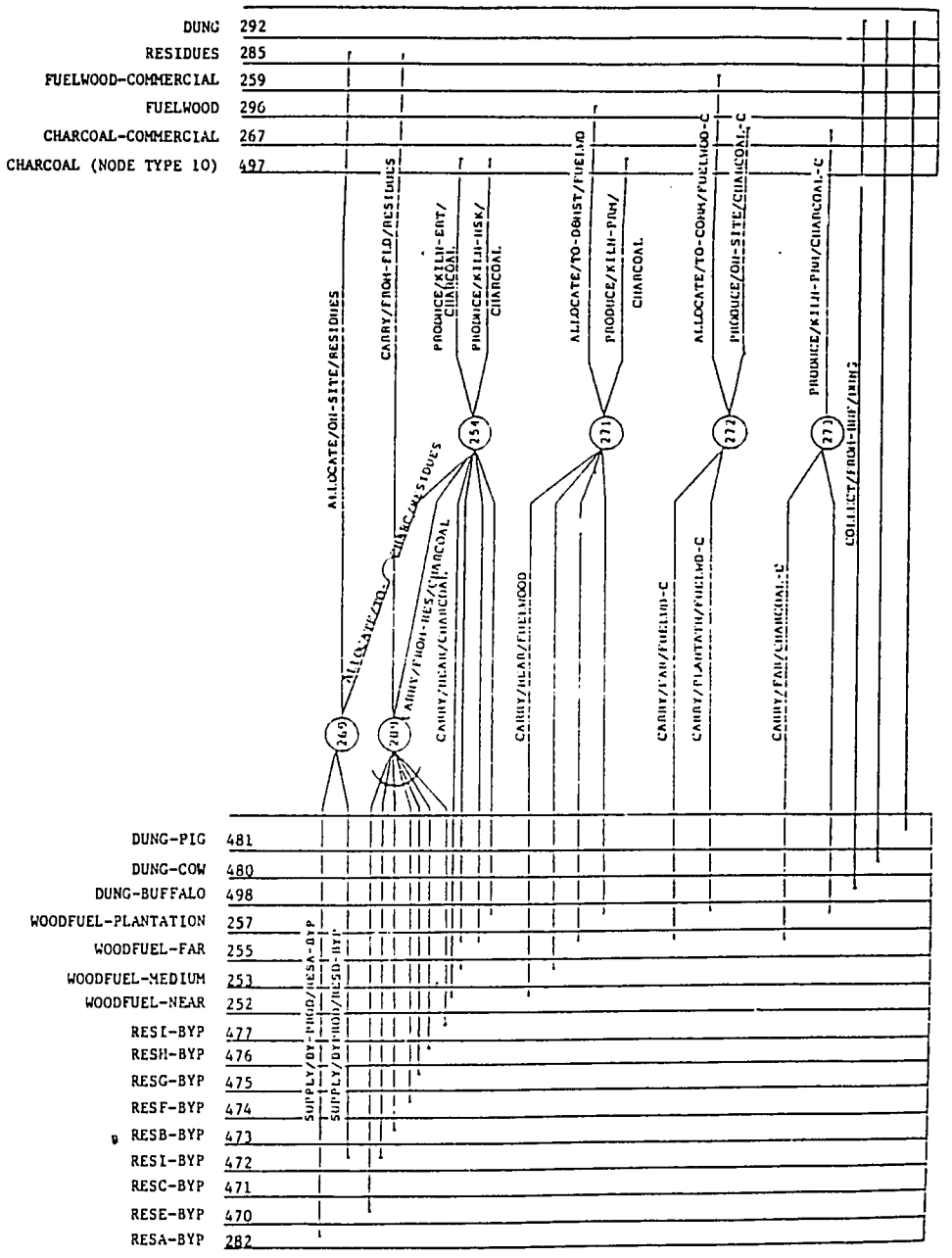
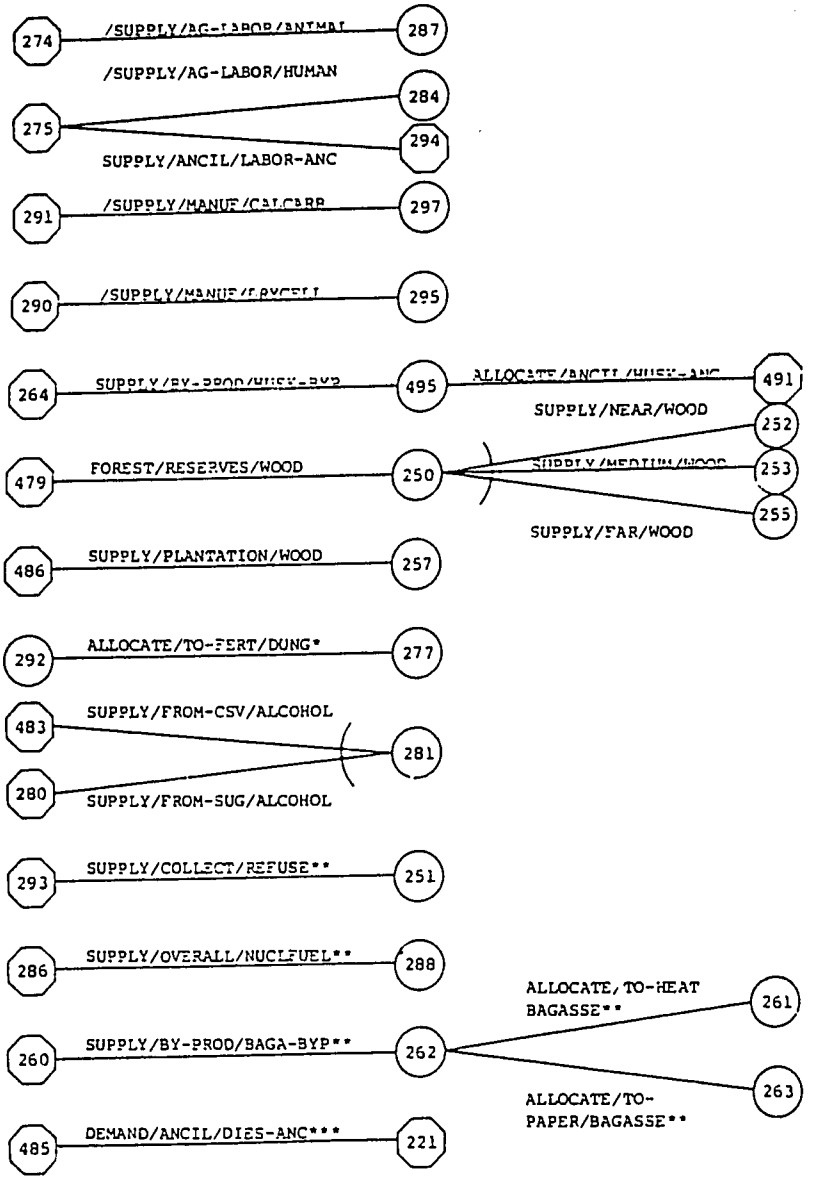


Fig. 3.9 Othrsup 2: Other Supply Sources



* This link now appears in the RURAL2 subsector.
** LINK appears in subsector "OTHRSUP3".
*** LINK appears in subsector "OTHRSUP4".

Table 3.2 Households Energy Consumption, National, 1980. Annual Per Capita

Source / Use	Fuelwood kg	Charcoal kg	Paddy Husk kg	Paddy Straw kg	Coconut Branch kg	LPG kg	Kerosine l.	Gasoline l.	Diesel l.	Electricity Kwh	Drycell pieces	Calcium Carbide kg	Subtotal	%
Cooking HJ %	108.45 1,769.1 42/66	84.89 2,425.1 57/97	2.54 31.5 .7/10	-	-	0.33 15.4 .4/100	0.06 2.3 .05/.7	-	-	1.93 8.9 .2/12	-	-	4,250.3	70.8
Lighting HJ %	-	-	-	-	-	-	8.74 339.6 89/99	-	0.34 13.3 3.5/58	5.91 21.2 5.4/38	5.25 0.009 0/33	0.46 9.2 2.4/100	383.3	6.4
Ironing HJ %	-	1.77 50.6 92/2	-	-	-	-	-	-	-	1.25 4.5 8/8	-	-	55.1	0.9
Industry HJ %	9.67 157.7 36/6	0.46 15.1 3/.5	1.76 21.8 5/7.2	-	-	-	-	-	-	-	-	-	432.1	7.2
Heating HJ %	28.4 463.3 95/17	-	-	1.11 13.8 2.9/21	0.69 8.8 1.8/41	-	-	-	-	-	-	-	485.9	5.1
Fumigation HJ %	17.16 279.9 78/10.5	-	0.95 11.8 3.3/4	4.26 52.8 15/79	1.0 12.8 3.6/59	-	-	-	-	-	-	-	357.3	6.0
Appliances HJ %	-	-	-	-	-	-	-	-	-	5.32 19.2 100/34	7.75 0.013 0/0.67	-	19.2	0.3
Pump HJ %	-	-	-	-	-	-	-	0.19 6.68 33/100	0.25 9.8 46/42	1.17 4.2 21/7.5	-	-	20.7	0.3
Subtotal	163.68 2,670	62.17 2,489.8	24.55 304.6	5.37 66.6	1.69 21.6	0.35 15.4	8.81 342.3	0.19 6.98	0.59 23.1	15.58 56.1	13.0 0.02	0.46 9.2	6,004	130
Percentage	44.5	41.-	5.1	1.1	0.4	0.3	5.7	0.1	0.4	0.9	0.	0.2	100	

Table 3.3 Rural Household Energy Demands.

Link Description Activity/Fuel	Nodes Up-stream	Nodes Down-stream	1981 Energy Inflow (Tcal)	Util. Eff. (%)	1981 Energy Outflow (Tcal)	Market Allocation (%) 1981	1986	1991	1996	2001
Cooking/Biogas	296	454	0	33	0	0	0.2	2	4	7
/Husk	495	454	253	44	111	1.7	1.7	1.7	1.7	1.7
/Charcoal	497	454	19,498	22	4290	66	63	60	55	50
/Fuelwood (3-rack)	496	454	3,756	12	451	7	7	6	6	5
/Fuelwood (bucket)	496	454	10,467	14	1465	23	21	19	17	15
/LV Elec.	352	454	55	100	55	0.8	1	2	4	6
/Residues	285	454	0	14	0	0	0	0	0	0
/LPG	188	454	124	33	41	.6	5	10	15	20
/Lignite	068	454	0	33	0	0	0	0	0	0
/Kerosene	219	454	14	44	6	0	.1	.5	1	1
Lighting/Biogas	296	460	0	100	0	0	.02	.2	.4	.7
/Calccarb	297	460	0	100	0	2.4	2	1.5	1.5	1
/HSDiesel	229	460	107	100	107	3	1	.5	.5	.5
/Kerosene	219	460	2730	100	2730	88.7	85	82	75	70
/LPG	188	460	0	100	0	0	0	0	0	0
/LV-Elec.	352	460	170	100	170	5.4	10	15	20	25
Fumigate/Husk	496	453	95	100	95	3.3	3.3	3.3	3.3	3.3
/Residues	285	453	527	100	527	18.6	18.6	18.6	18.6	18.6
/Fuelwood	495	453	2250	100	2250	78.1	78.1	78.1	78.1	78.1
HH-Appli/Drycell	295	465	0.1	100	0.1	.1	.1	.1	.1	.1
/LV-Elec.	352	465	153	100	153	99.9	100	100	100	100
HH-Heat/Fuelwood	496	451	3725	100	3725	95	95	90	90	90
/Residues	285	451	182	100	182	5	5	10	10	10
HH-Indst/Charcoal	497	463	104	100	104	8	8	8	8	8
/Fuelwood	496	463	1254	100	1254	92	92	92	92	92
HH-WPump/Biogas	219	459	0	35	0	0	.02	.2	.4	1.
/HSDiesel	229	459	76	35	26.5	46	40	35	30	25
/Reg-Gas	205	459	55	20	11	33	30	25	20	20
/LV-Elec.	352	459	35	100	35	21	25	35	45	50
Ironing/Lv-Elec.	352	457	35	100	35	8	20	32	44	50
/Charcoal	497	457	403	100	403	92	80	68	56	50

Table 3.4 Energy Demanded for Land Preparation

	Total Mcal/rai	Gasoline[2] Tractor Mcal/rai (%)	Diesel[3] Tractor Mcal/rai (%)	Human[4] Hrs/rai	Human[4] Mcal/rai (%)	Animal[4] Hrs/rai	Animal[4] Mcal/rai (%)
Rice 1 Rice 2	8.013	(02)	(48)	32.6	(29)	4.6	(21)
Maize	.510	.003 (01)	.400 (78)	1.1	.076 (15)	0.085	.031 (06)
Rubber	.098	0	0	1.37	.098 (100)	0	0
Cassava	.555	0	.335 (60)	2.5	.18 (32)	0.11	.039 (07)
Bean	.271	.002 (01)	.181 (67)	1.16	.084 (31)	.01	.004 (01)
Sugar	.094	0	.062 (66)	4.4	.031 (33)	0.004	.001 (01)
Other Crops[1]	.274	.007 (03)	.156 (56)	1.4	.098 (36)	0.035	.013 (05)

Source: NEA Rural Survey, except where noted.

1. Data for all other crops is a rough average of data for kenaf, cotton, tobacco and coconuts.

2. Gasoline tractor demand assumes an energy conversion efficiency of 20%, therefore 100 Mcal consumed meets a demand of 20 Mcal.

3. Diesel tractor energy demand assumes a 20% fuel use efficiency.

4. To convert human and animal hours to Mcal, the following rough conversion factors were used:

   Animals = 0.5 hp-hr/hr
   Human = 0.1 hp-hr/hr

Table 3.5 Energy Demanded for Water Pumping (Mcal/rai)

	Total	Gasoline[1] (%)	Diesel[2] (%)
Rice 1	.058	.032 (56)	.026 (44)
Rice 2[3]	.058	.032 (56)	.026 (44)
Maize	.002	0	.002 (100)
Rubber	0	0	0
Cassava	0	0	0
Bean	.0014	.001 (100)	0
Sugar	.148	.007 (05)	.141 (95)
Other Crops	.220	.086 (39)	.134 (61)

Source: NEA Rural Survey.

1. Assuming a gasoline pump efficiency of 20%.

2. Assuming a diesel pump efficiency of 20%.

3. No data was available to show the expected variable pumping requir ments between first and second rice.

Table 3.6 Energy Demands for Other Agricultural Machinery

	Total Mcal/rai	Gasoline[1] Tractor Mcal/rai (%)	Diesel[1] Tractor Mcal/rai (%)	Human Hrs/rai	Human Mcal/rai (%)	Animal Hrs/rai	Animal Mcal/rai (%)
Rice 1	5.392	.023 (00)	1.434 (27)	48.8	3.52 (65)	1.15	.042 (08)
Rice 2	5.392	.023 (00)	1.434 (27)	48.8	3.52 (65)	1.15	.042 (08)
Maize	0.188	.015 (08)	.050 (27)	1.58	.114 (61)	0.02	.008 (04)
Rubber	0.148	0	0	2.05	.148 (100)	0	0
Cassava	0.310	.020	.010 (03)	3.74	.270 (87)	0.03	.010 (03)
Bean	0.163	.019 (12)	.010 (06)	1.75	.126 (77)	0.003	.008 (05)
Sugar	0.047	0	0	0.65	.0465 (99)	0.001	.0005 (01)
Other Crops	0.187	.034 (18)	.002 (01)	2.04	.147 (79)	0.01	.004 (02)

Source: NEA Rural Survey.

1. Gasoline and diesel energy demand figures assume a 20% fuel use efficiency.

Table 3.7

	Fertilizer Use (Kg/rai)		Average[1] Crop Yield	Nitrogen Demand[2] (Kg N/ton of crop)	
	Manure	Chemical Fert.	Tons/rai	Manure	Chemical Fert.
Rice 1	40	5.6	0.27	2.3 (41.5%)	3.3 (58.5%)
Rice 2	0	50	0.61	0	12.3 (100%)
Rubber	0	8	0.06	0	20.0 (100%)
Cassava	0	8	2.28	0	0.57 (100%)
Bean	15	8	0.12	1.9 (16%)	10.3 (84%)
Sugar	10	8	6.78	0.03 (10%)	0.26 (90%)
Other Crops	40	8	0.25	2.6 (33%)	5.2 (67%)

Sources: 1980/81 Agricultural Statistics of Thailand; the NEA Rural Energy Survey; and Meta Systems Rural Energy Survey.

1. Average yield is the 1981 yield.

2. Assuming that chemical fertilizer is 15% nitrogen, and that manure is 1.5% nitrogen.

Table 3.8

Crop	1981 Total Production*	Cult.Area* (raix10^6)	Energy Demand			Fert.Use (Kton N)
			Land Prep.	Pumping	Agr. Mach.	
Rice 1	15.405	56,845	454.9	33.0	306.5	81.9
Rice 2	1.963[1]	3,229[1]	25.9	1.9	17.4	24.1
Maize	2.998	8,949	4.56	.016	1.68	17.2
Rubber	.465	7,750	0.78	0	1.15	10.7
Cassava	16.54	7,251	4.03	0	2.25	6.3
Bean	.49	4,242	1.15	.006	0.69	5.6
Sugar	19.854	2,927	0.27	.433	0.14	3.7
Other Crops	1.875	7,428	2.04	1.634	1.39	13.4

1. These are the 1981 figures, since 1980 had abnormally low production and land use for this crop.

*Source: Agricultural Statistics of Thailand 1980/81, Ministry of Agriculture and Crops, Bangkok, 1981.

Table 3.9

Crop	Residue Type	Energy per Unit of Product Mcal/ton
Rice 1	rice stalk[1]	4,000
	rice straw[1]	4,000
	husk	1,000
Rice 2	rice stalk	2,000
	rice straw	2,000
	husk	1,000
Maize	cob[2]	0
	stalk	3,000
Rubber	leaves & branches[2]	0
Cassava	leaves & stalk	1,500
Bean	leaves & stalk	10,000
Sugar	leaves	600
Other	residues	2,000

[1] Rice straw and rice stalk are the same product, except that straw is brought in with the harvest and stalk remains in the field. We have assumed here that 50% is harvested and that rice 2 has only half the total stalk/straw.

[2] Corn cobs and rubber leaves & branches were assumed to have zero usable energy content since data regarding their use in Thailand was not available at the time of the study.

Table 3.10

Crop	Annual Growth Rate	5-Year Growth Rate
Rice 1	2.8%	14.8%
Rice 2	7.8%	45.6%
Maize	6.5%	37%
Rubber	8.3%	49%
Cassava	0.3%	1.5%
Bean	2.5%	13.1% (assumed)
Sugar	2.5%	13.1%
Other	2.5%	13.1% (assumed)

Source: Thai official macroeconomic projections.

fuel choice made on th basis of cost or energy efficiency. The energy efficiencies used in this model are indicated in Table 3.3.

Agricultural Demand Sector

The agricultural demand sector of the rural EMP model was structured to reflect the energy resources used in each of the major crops grown in Thailand. The choice of crop and energy consumption activity was dictated by data availability. The NEA Rural Survey presents data regarding energy consumed in land preparation, water pumping, and other agricultural machinery for several of the major crops. This survey was the principal source of data for this section. The crops chosen for representation in the model were: rice (first and second plantings were considered separately), maize, cassava, rubber, sugar cane, beans (castor, soy and mung) and a final category which includes all other agricultural products.

The link-node structure of the agricultural demand sector is described in Figures 3.6 and 3.7. These Figures indicate that crop production has land preparation, water pumping, agricultural machinery and fertilizer inputs and produces agricultural residue by-products.

The data for energy consumed by each crop for land preparation, water pumping and agricultural machinery is displayed in Tables 3.4, 3.5 and 3.6 respectively.

In addition to these standard energv consumption activities, we have examined the use of fertilizer in agriculture because the use of manure as a fertilizer competes with its use as a fuel (in the production of biogas, for instance). These data were not readily available from the NEA Survey and were therefore estimated using chemical fertilizer consumption information from the 1980/81 Agricultural Statistics of Thailand and some data on manure application that were collected during the Meta Systems rural energy survey. The results are displayed in Table 3.7 and the necessary assumptions are described in the accompanying footnotes.

In order to determine the total energy flows associated with the different crops, the total production levels were required. These were reported in the 1980/81 Agricultural Statistics of Thailand and are displayed in Table 3.8 Total energy flows by activity and crop are also reported in this table. Some manipulation of the data was required to adjust for some abnormally bad crops in the 1981 baseline year and to properly represent the "Other Crops" category. The exact procedure is described in the footnotes to that table.

The leaf, stalk and processing residues of many plants can be used for various energy-related purposes. Some residues are presently burned for heat or fumigation. Some residues have potential conversion to charcoal, biogas or producer gas. For this study we have assumed that residues are produced as a constant ratio of primary crop production. The production ratio and energy content data used in this study are presented in Table 3.9. Most of the data was available in the reports of the Meta Systems Rural Survey. The remainder was estimated from various studies of crop residue production in other countries.

Forecasts of agricultural production were available from the NESDB macro-model of Thailand (1979) for most of the major crops (see Table 3.10). Growth of other crops was estimated from this information. The growth of energy intensivity (i.e. the increase in energy use per unit of agricultural production) is assumed to be 15% for every 5-year period from 1981 to 2001. Table 3.6 indicates the forecasts and their sources. Tables 3.11, 3.12 and 3.13 show the resulting energy use forecasts. Fertilizer use was assumed to grow at 3% per year for rice and 4% per year for all other crops (slightly below the historical use of chemical fertilizer in each category). Since it was assumed that manure use would not increase, all this growth is shown as a demand for chemical fertilizer.

One purpose of the rural sector EMP model is to evaluate the future demand for alternative fuels. In order to permit different fuels to enter the L.P. solution in future years, the fuel choices were relaxed by 10% for each successive five-year period. The alternative fuel choices include gasohol, producer gas, dual fuel, wind and biogas (in addition to such conventional fuels as LPG, gasoline, diesel, electricity, animal power and human power). The allocation of these fuel choices to a purpose (such as land preparation or water pumping) is shown in Figure 3.7. Costs for the different pieces of farm equipment and fuel utilization efficiencies of that equipment are shown in Appendix A-3 in Meta Systems Inc.'s Report, Vol.II.

Several fuels have been identified as potential sources of energy for the various households. However, the degree to which any new fuel or conversion technology will penetrate into the household fuel market in Thailand is a function of many variable which are beyond our ability to forecast with any confidence. Fuel choice in the household sector is probably due more to habit than to cost minimization. The baseline market allocation scenarios were provided by the NEA Rural Survey. The future market allocation assumptions are indicated in Table 3.3.

The projection methodology for household demand employed in the original EMP model is a simple extrapolation of the base year consumption by the population growth rate: $E_t = E_0(1+r)^t$ where "r" is the rate of population growth. The only modification was to incorporate some of the planned extension of rural electrification by having a faster growth rate in lighting and other appliances using electricity.

Household energy demand forecasts used in the EMP model are as follows:

- cooking 2.1% annual increase
- lighting and appliances 6.8% annual increase

This study used the lighting figure for lighting and appliances and the cooking figure for all other activities.

It seems clear that given the shifts in choice of fuels consumed over the last decade as well as a rising standard of living in rural areas, projection of rural household energy demand should, in addition to population growth, incorporate some income effects and, perhaps, some developmental policy targets. However, due to the limitations of time, this could not be done in the study.

Table 3.11 Energy Use for Land Preparation

	1981 Crop Prod. (Mton)	1981 Land Use (rai 10^3)	1981 Energy Use (Mcal/rai)	1981 Energy Use (Tcal)	Forecasted Energy Demand (Tcal/Mton of Product)				
					1981	1986	1991	1996	2001
Rice 1	15.4	56,845	8.013	454.9	29.53	34.2	40	46	53
Rice 2	1.96	3,229	8.013	25.9	13.19	15.3	18	21	24
Maize	3.00	8,949	0.510	4.56	1.52	1.8	2.0	2.4	2.7
Rubber	0.465	7,750	0.098	0.78	1.68	1.9	2.3	2.6	3.0
Cassava	16.54	7,251	0.555	4.03	0.24	0.28	0.3	0.4	0.4
Bean	0.49	4,242	0.271	1.15	2.35	2.7	3.2	3.6	4.2
Sugar	19.85	2,927	0.094	0.27	0.014	0.016	0.019	0.022	0.025
Other	1.88	7,428	0.274	2.04	1.09	1.3	1.5	1.7	2.0

Table 3.12 Energy Use for Water Pumping

	1981 Mcal/rai	1981 Total (Tcal)	Forecasted Energy Demand (Tcal/Mton of product) 1981	1986	1991	1996	2001
Rice 1	0.58	33.0	2.142	2.5	2.9	3.3	3.9
Rice 2	0.58	1.9	0.97	1.12	1.3	1.5	1.7
Maize	.0018	0.016	0.005	.006	.007	.008	.010
Rubber	0	0	0	0	0	0	0
Cassava	0	0	0	0	0	0	0
Bean	.0014	0.006	0.012	.014	.016	.019	.022
Sugar	.148	0.433	0.022	.025	.03	.03	.04
Other	.220	1.634	0.87	1.00	1.2	1.4	1.6

Table 3.12 Energy Use for Agricultural Machinery

	1981 Mcal/rai	1981 Total (Tcal)	Forecasted Energy Demand (Tcal/Mton of product) 1981	1986	1991	1996	2001
Rice 1	5.392	306.5	19.9	23.	27.	31.	36.
Rice 2	5.392	17.4	8.9	10.	12.	14.	16.
Maize	.1878	1.68	0.56	0.65	0.75	0.9	1.0
Rubber	.148	1.147	2.47	2.9	3.4	3.9	4.5
Cassava	.310	2.25	0.136	0.16	0.18	0.21	0.24
Bean	.1634	0.69	1.41	1.64	1.9	2.2	2.5
Sugar	.0473	0.138	0.007	0.008	0.009	0.011	0.013
Other	.1870	1.389	0.741	0.86	0.99	1.15	1.33

Rural Industry

This sub-sector is not yet operative in the rural model since no data on base year consumption were available.

Rural Transport

As referred to earlier, rural transport was explicitly broken out from the aggregated data contained in the original EMP model. In this context, the results of the BCEOM study "Studies of Energy Policy for Transportation," carried out for the Ministry of Transport, were very useful.

Rural transport was divided into 3 main categories as follows:

Category	Mode	Unit
Rural/Provincial Passenger Transport	Light Bus Light Commercial Bus	Million Passenger Kilometers (MPKM)
Rural Passenger Transport	Motorcycle	Million Vehicle Kilometers (MVKM)
Rural Freight Transport	4-wheel truck (light) 6-wheel truck (heavy) 10-wheel truck (heavy)	Million-Ton KM (MKM)

In the RCDM study, the following data on passenger transport for different categories of roads are provided for 1978 (million vehicle km):

Mode	National & Provincial Rd.	Rural Rd.	Total
Cars & Taxi	4304.5	--	4304.5
Light Commercial Bus	1320.0	246.7	1566.7
Light Bus	3281.0	1054.0	4335.0
Heavy Bus	1481.3	--	1481.3
Total	10,386.8	1300.7	11,687.5

In the same study, the average passenger occupancy rate per vehicle has been estimated as follows:

	Occupancy (passengers/vehicle)
Private Cars/Taxi	2.6
Light Bus/Light Commercial Bus	6.05
Heavy	28.05

This was used to obtain the following data on million-passenger km for the various modes:

	National/Provincial Rds.	Rural Rds.	Total
Cars & Taxi	11,191.7	--	11,191.7
Light Comm. Bus	7,986.0	1,492.5	9,487.5
Light Bus	19,850.1	6,376.7	26,226.8
Heavy Bus	41,550.5	--	41,550.5
Total	80,578.3	7,869.2	88,447.5

Comparison with the results in the EMP estimates show that the latter are clearly non-credible. In fact, their category, which includes "Provincial Passengers" (designated in node 942), seems to be underestimated by a factor of at least 7.

We assume that only "rural roads" are relevant for passenger bus transport in rural areas. The base year figures have been projected to grow at the same rate as the rural population. The forecasts are as follows:

Year	Passenger (Bus) Transport (MPKM)
1981	8,486.7
1986	9,301.4
1991	10,185
1996	11,153
2001	12,223

An improved projection methodology could be utilized to bring in income effects, rural road construction programs, etc., but due to lack of time, this was not carried out for the present study.

Transport by motorcycle is increasingly becoming an important form of passenger transport in rural areas. The BCEOM study cited earlier estimates that on national/provincial roads and rural roads, motorcycle transport amounted to 3297 and 880 million vehicle-km respectively in 1978. Since motorcycles are not generally used for long-distance, inter-urban transport, it was assumed that the usage of motorcycles on national/provincial highways and rural roads essentially represents rural motorcycle use. (This assumption is open to some question depending on further data in this area.) To align the 1978 figure with the 1977 base year (used for the EMP projections), the 1970-78 growth rate of motorcycle registrations, 9.8%, was used to project the 1978 vehicle-km back to 1977. This gave a total of 3803.7 million vehicle-km for rural motorcycle transport in 1977.

The projection methodology used by the EMP was to forecast the total number of motorcycles by regression analysis using real GDP as the only explanatory variable. The growth rate of motorcycle vehicle-km was assumed to be equal to that of the number motorcycles, although some improvements in this approach to projection can be suggested (see the last section). For

lack of time, the growth rate of the EMP study was assumed for the initial runs of the model. This produced the following forecast for rural motorcycle vehicle-km (in the base case EMP, GDP growth scenario):

Year	1977	1981	1986	1991	1996	2001
Motorcycle (MVKM)	3,803.7	5,305.1	8,194.1	13,135.5	19,209.6	28,094.8

Freight transport in the national model occurs by three modes: Light Truck (4-wheel), Heavy Truck (10-wheel and 6-wheel), and Railway. Waterborne modes (coastal and inland) are treated separately. The existing EMP model has no separate category for rural freight transport (or, as pointed out earlier, for any rural transport).

To separate out rural freight transport, the data base in the BCEOM study mentioned earlier was used. From working papers #4 and #5 of Meta Systems Inc's Report, Vol. II, the vehicle-km of freight transported by various classes of trucks and roads in 1978 (excluding urban roads) were as follows:

Vehicle-Km of Freight Transport, 1978

Mode	National/Provincial Roads (MVKM)	Rural Roads (MVKM)
Light Truck	3,643.3	1,054.0
Heavy Truck	4,151.4	166.3
- 6-wheel	2,453.1	118.8
- 10-wheel	1,698.3	47.5

The average loads (tons/VKM) for different vehicles (from the BCEOM study) are as follows:

Vehicle	Tons/VKM
Light Truck	1.2
6-wheel Truck	3.4
10-wheel Truck	7.3

Putting this data together, the freight transported by various classes of trucks (in units of million ton-km) for the different road categories is as follows:

Ton-Km of freight Transport, 1978

Mode	National/Provincial Roads (MTKM)	Rural Roads (MTKM)	Total (MTKM)
Light Truck	4,371.96	1,264.8	5,636.76
Heavy Truck	20,738.13	750.67	21,488.8
- 6-wheel	8,340.54	403.92	8,744.46
- 10-wheel	12,397.59	346.75	12,744.34

In order to project freight transport for future years, the methodology of the existing model was adopted due to time limitations. This methodology is based on the assumption that the growth rate of ton-km of freight is identical to the growth rate of the number of trucks. The latter was assumed to be a function of the real GDP and a coefficient estimated through a standard regression procedure. Various future scenarios of real GDP growth then generated different scenarios of ton-km, starting from the base year (1977) data.

Using the base case GDP growth assumption (scenario I in the EMP study) and the estimated regression coefficients, the base case growth rate for freight (ton-km) transport is 9.73% per annum for the years 1977-81, 6.6% for 1981-86, and 8% for 1986-2001.

In order to project rural freight transport, it was assumed that all rural freight will be transported by the various categories of trucks on the rural roads as contained in the above table.

The 1978 data for the light and heavy trucks on rural roads were discounted back to the base year 1977 of the EMP study using the 1977-81 growth rate, and then projected forward using the above growth rates. The results are shown below.

Projections of Rural Freight Transport
(MTKM)

Year	Light	Mode 6-wheel	Heavy 10-wheel	Subtotal	Total
1977	1,152.65	368.11	316.00	684.11	1,836.76
1981	1,519.13	475.15	416.47	701.62	2,420.75
1986	2,059.36	669.17	574.44	1,243.61	3,338.97
1991	3,189.04	1,018.45	874.27	1,892.72	5,081.76
1996	4,794.99	1,531.33	1,314.54	2,845.87	7,640.86
2001	7,204.34	2,300.78	1,975.07	4,275.85	11,480.19

In completing this analysis, numerous inconsistencies in the existing EMP model data base and projection estimates were uncovered. Eventually, the entire (urban and rural) freight transport by all modes was re-estimated. Details of this are provided in Technical Appendix A.1 in Meta Systems Inc.'s Report, Vol. II.

Other Supplies

The OTHRSUP2 sector of the rural EMP model provides energy forms other than petroleum or grid electricity for use in the model. The network representation of these links and nodes are presented as Figures 3.8 through 3.11. The data used in those links are described below.

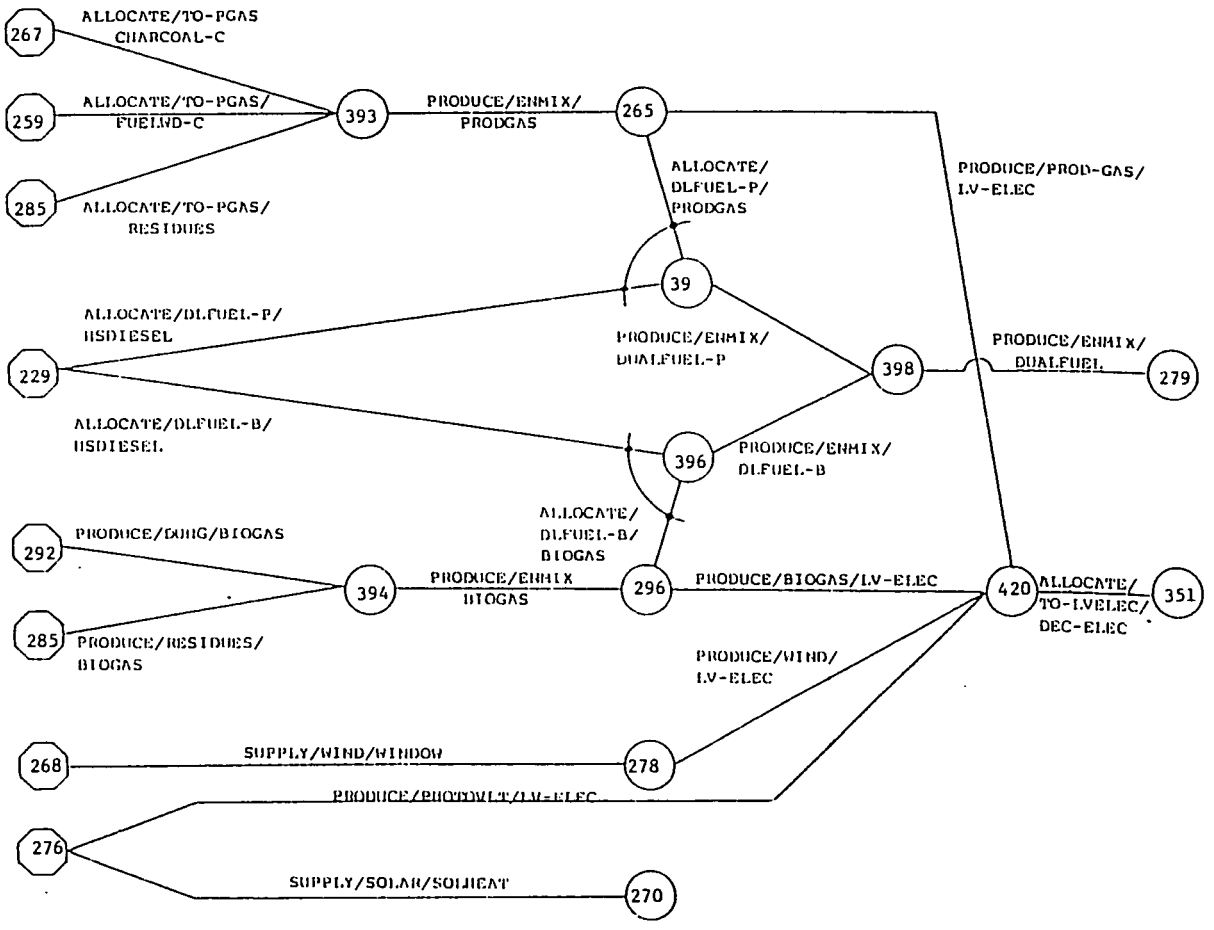
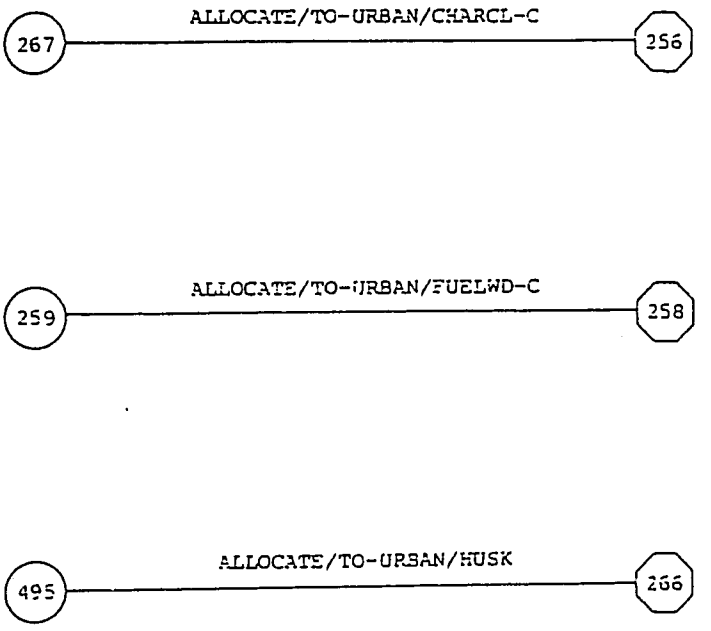


Fig. 3.10 Othrsup 2: Other Supply Sources

Fig. 3.11 OTHERSUP2: Urban Demands On Other Supply Sources*



* Separation of the rural sector model from the EMP has made these links necessary.

The major resource in the OTHRSUP2 sector is the woodfuel which is used as fuelwood or converted to charcoal. Virtually all of the woodfuel is obtained from unmanaged forest areas and from trees which grow in areas which are primarily used for non-forestry purposes. However, many recent reports indicate that the rate of woodfuel use far exceeds the regeneration rate of existing forests. A recent report by NEA showed a 7.7% forest area depletion rate over the past 10 years. The rural EMP model has therefore been provided with a woodfuel plantation resource option, capable of producing far greater yields per rai. The assumptions are presented below.

Wood Yield - Natural Forest - 2.3 cu.m/ha - (.375 cu.m/rai)
Plantation (fast-growing, managed) - 20 cu.m/ha - (3.2 cu.m/rai)

NEA Historical Data (by Supot Tadyu and Tammachart Sirivadhanakul)

Forest Area (million rai)	82.7	76.6	70.7	65.3
Margin Forest (million rai)	3.4	3.3	3.2	3.1
Total (million rai)	86.1	79.9	73.9	68.4

Average depletion rate 1970-78 = 7.7% for forest and 3.4% for margin forest. Wood density - 400 kg/cu.m/3

Demand Forecast (NEA, R. Nathan)

	1980	1981	1986	1991	1996
Rural Woodfuel Cons.* (million cu.m)	31	31.2	32.8	33.7	34.5
Urban Woodfuel Cons. (million cu.m)	10.4	13.2	14.7	15.7	18.0
Total	41.4	44.4	47.5	49.4	52.5

* Urban woodfuel consumption is taken from the EMP model.

Given these assumptions, the following scenarios were generated. First, the forest area is depleted at 6% until 1986, when the plantations are ready to be used, and depleted at 0% thereafter. Second, the same pattern is followed, but the plantations are not operating until 1991. These scenarios are shown below:

Scenario 1	1981	1986	1991	1996	2001
Forest + Margin (million rai)	65	48	48	48	48
High Yield Plant. (million rai)	0	----------as needed---------			

Scenario 2

Forest + Margin (million rai)	65	48	35	35	35
High Yield Plant. (million rai)	0	0	----as needed-----		

The woodfuel data is entered into these two resource links (link 340 - FOREST/RESERVES/WOOD and link 710 - supply/PLANTATION/WOOD) with maximum energy flow constraints. The forest is constrained (at an energy flow level equivalent to the available rai in the table above) from 1986 on in the first scenario and from 1991 on in the second. The plantation is constrained at zero flow for 1981 in the first scenario and for 1981 and 1986 in the second scenario. The forest reserves pass through the downstream node into a far, medium, and near distance from the farms which collect the wood. The allocation of forest to these different distances is accomplished by a PRAL-NOR data entry of 35% far, 25% medium and 40% near.

Residues are represented in the rural EMP as by-products of crop production. The residue by-product ratios appear in the RURAL2 section of the rural EMP. The OTHERSUP2 section of the model contains resource links in the form SUPPLY/BY-PROD/RESA-BYP. These links contain an efficiency which indicates the portion of the residue which is collectable (90% has been assumed uniformly) and a non-binding market allocation (the downstream nodes are unconstrained) which indicates the expected contribution of each residue to the downstream node. All these by-product links feed into two downstream links: one for residues carried to the farm with the harvested crop (e.g., rice husk) and one for residues left in the field.

The wood supply function is based on distance to source. The Meta Systems survey data on distance to primary and secondary sources was aggregated assuming that those mentioning a second source use it for 1/3 of their supply. The resulting distribution is as follows:

41% travel less than 1 kilometer
24% travel a median of 2 kilometers
25% travel a median of 4 kilometers
6% travel a median of 8 kilometers
4% travel a median of 20 kilometers.

For the purposes of this model. This distribution has been collapsed as follows:

40% travel less than 1 kilometer
25% travel a median of 2 kilometers
35% travel a median of 6.5 kilimeters

Assuming a cross-country walking speed of 4 kilometers per hour, the respective median travel times round-trip would be 15 minutes, 1 hour, 2 hours, 4 hours and 10 hours. For the further distances it is assumed that animals and carts are used. They are also used for medium distances in the hilly areas of the north. However, the use of animals and carts is not expected to affect travel times. The collection of wood fuels for household use is a responsibility shared by all members of the family. During the off-peak season and for sources at greater distance, adults, especially males, are more likely to be involved, whereas during the peak labor season and for nearer sources, the children are more likely to have responsibility. For the supply curve for village fuelwood, the cost of labor was computed assuming 1/2 the hourly wages for farm labor for all

distances. Assuming a one-hour collection time for a 15-kilogram load and an average load of 50 kilograms for the farthest distance, 25 kilograms for the medium distances and 12 kilograms for short distances, the resulting supply costs are:

	Mean dist. (km)	Travel time (hrs)	Load (kg)	Collection time (hrs)	Total time (hrs)	Labor Energy* (Kcal/kg)	Labor Energy (cal) per Energy Content (Kcal) Wood	Char	Residue
near	0.67	0.33	12	0.8	1.13	5.8	2.23	2.26	2.39
medium	2.0	1.0	25	1.7	2.7	7.8	2.56	1.33	2.74
far	6.5	3.2	50	3.3	6.5	9.4	3.08	1.61	3.30
plantation	10.0	5.0	50	3.3	8.3	12.0	3.93	2.05	4.21

* Assuming that human labor provides 72 kcal/hr.

Energy contents are as follows: fuelwood is 4250 kcal/kg (dry) divided by 1.4 (assumed in-site to dry weight ratio) to give 3050 kcal/kg; charcoal is 6350/1.09 or 5850 kcal/kg; residues are roughly 3700/1.3 or 2850 kcal/kg.

The labor inputs in this table are entered into the various "carrying" links in the OTHERSUP2 portion of the model. These links are provided with market allocations that correspond to the travel distance distribution cited above. Note, however, that the "ancillary" labor inputs to wood, residue and charcoal carrying differ from those presentd above. This has occurred for two reasons. First, the costs in the present model (Appendix A.4 in Meta Systems Inc's Report, Vol.II) are wrong. The new version is provided in Appendix A.6 in Meta Systems Inc's Report, Vol. II. Second, the EMP software limits the size of numbers entered into the data base. All numbers smaller than .001 are set to zero. Therefore, ancillary labor has been changed from .175 million baht/Tcal[--12.5 (baht/hr)/0.72 (Kcal/hr) = 0.175x109 (baht/Tcal)--] and the ANCIL-LBR links are increased by a factor of 1000.

The supply of wood for commercial purposes has a different cost function because:

- Large quantities must be collected by hired labor;
- Large quantities must be obtained from forests;
- Fees, both formal and informal, need to be paid to collect wood from the forest;
- Large quantities must be transported by truck; and
- Rural industries tend to cluster in market towns which are at a greater distance from forests.

Commercial fuelwood and charcoal have therefore been costed according to reported purchase prices rather than rough carrying cost estimates. These costs are .28 baht/kg for fuelwood and 3 baht/kg for charcoal.

Although the data above and the rural EMP data in Appendix A.4 in Meta Systems Inc's Vol. II provide charcoal-carrying costs, forest kiln sites are not used widely in Thailand. The wood for charcoal production is brought to a kiln site near the home, converted and then stored in the house. Therefore, the charcoal-carrying function is identical to that for wood production. There is some commercial charcoal production of mangroves in the south for industrial use and some charcoal production in forest areas for urban domestic fuels, but in the rural area very little charcoal is sold, and this mostly in the rainy season or in wood-scarce regions. Appendix A.6 in Meta Systems Inc's Report, Vol. II provides corrections to the rural EMP input file to properly reflect this characteristic.

Residues are assumed to originate at a medium distance from the farm unless they are harvested with the crop and carried to the farm anyway (as happens with rice husk, rice straw and corn cobs). The carrying cost functions in the above table are used in the resource link for all the residues which do remain in the field. These links are numbered 210 and 211 in the input data presented as Appendix A.4 in Meta Systems Inc's Report, Vol. II.

Dung is used in biogas generation and as fertilizer, and in many parts of the world it is burned directly. Estimates of the total dung supply for this model were developed from data on buffalo, cow and swine populations reported in the 1980/81 Agricultural Statistics of Thailand, and from calorific content measurements made in the Meta Systems Rural Survey. Table 3.14 presents this data in a form similar to that which was entered into the Rural sector of the EMP model.

The other energy resources presented in the OTHRSUP2 sector of the model are human energy, animal energy, wind, solar, bagasse, calcium carbide, and drycell batteries.

Human and animal energy were not considered in the original EMP, yet they do have a clear role as an alternative energy source for many of the activities characterized in the demand portion of the rural EMP. The energy content of labor has been estimated as:

- Human labor = 72 kcal/hour
- Animal labor = 240 kcal/hour

Human energy is shown in terms of a rural wage rate of 25 baht/day (or 12.5 baht/day for domestic carrying and kiln operating activities). This information is presented in links 52 and 53 (in the present configuration). Animal energy costs are presented in link 51 as 150 baht/mcal. This relates to an animal rental rate of 36 baht/hour.

Wind, solar and bagasse use as energy resources are presented in the original EMP model and report. The links that were provided in that model have been inserted into this model untouched. New links which generate electricity from solar and wind energy have been created.

Table 3.14

	1980 population	Dry Dung Prod./ Animal (Kg/day)	Energy Content (Kcal/Kg))	Total Annual Dry Dung (Mton)	Total Annual Energy (Tcal)
buffalo	5,650,800	4.5	2,820	9.32	26,288
cows	3,938,200	2	3,070	2.95	9,060
swine	3,020,400	.55	3,570	0.60	2,140
Total	12,609,400	2.8	2,912	12.87	37,480

Dry dung production:

The Meta Systems survey measured 5.6 kg/day for mature buffalo and 2.5 kg/day for young buffalo. The numbers used weigh the adult contribution as roughly twice the young buffalo contribution.

Calcium carbide and drycell are included in the OTHRSUP2 section (links 670 and 680) because they appeared in the NEA rural survey. Calcium carbide is a fuel for lighting, and drycell batteries are used for some household appliances. These have been entered solely for structural consistency; no costs were provided at this time.

The energy conversion devices presented in this model transform some of the raw energy resources aleady described in this section to more usable forms of energy such as biogas, shaft power, or electricity. The links providing this information include efficiency and cost data for biogas, producer gas, dual fuel, biogas to electricity, producer gas to electricity, solar heat, photovoltaics, wind to mechanical energy, wind to electricity, and alcohol from sugar or cassava. The cost and efficiency assumptions for these technologies are presented in Appendix A.3 in Meta Systems Inc's Report, Vol. II.

The Meta Systems survey examined three types of charcoal kilns commonly used in Thailand: the earth mound, rice husk, and permanent kiln. The data collected for each of these included: mean conversion efficiency, mean load, kiln operating time and number of kiln operators (though the latter three data elements had smaller samples).

The observations in the Meta Systems report led to the estimates in Table 3.15.

This information has been reported in the three links providing domestic charcoal production costs. The commercial charcoal kiln costs have beer set equal to an assumed commercial charcoal purchase price of 3 baht/kg.

Several other links appear in the OTHRSUP2 section of the model; still others appear in OTHRSUP3 and OTHRSUP4.

The remaining links in OTHRSUP2 have been placed there to establish urban demands for fuelwood, charcoal and husk. These links, 140, 150 and 160, are not necessary if the rural EMP is run with the complementary segment of the original EMP, but they are necessary when the rural EMP alone is run. When they are run together, the FLOW-LEV stated in these links are ignored. The flow level data now in the rural EMP was taken from the original EMP output.

OTHRSUP3 consists of links which are not necessary for running the rural EMP alone, but which are necessary when the two models are run together. These links appear in OTHERSUP, but since that segment will be suppressed if the two models are run together, they must be repeated here. They are not included in the rural EMP since they do not interact with any nodes in OTHRSUP2 or RURAL2.

Table 3.15

Charcoal Kiln Parameters

	Efficiency	Mean Load (kg)	Labor(Men)	Firing Time (days)
Clay permanent kiln	.49	700	2.5	7
Earth mound kiln	.36	200	2	5
Rice-husk mound kiln	.43[1]	100	1	2

For the purposes of this model, the following transformations have been made from the survey data:

	Efficiency	Labor	Labor (GCAL/TCAL)[2]	Husk (TCAL/TCAL)
Clay permanent kiln	.49	.11	8	
Earth mound kiln	.36	.28	20	
Rice-husk mound kiln	.43	.10	7	1.4[3]

1. Excluding rice husk energy.
2. These data differ from those in the data file. See the corrections in Appendix A.6. in Meta Systems Inc.'s Report, Vol. II.
3. Meta Systems' estimate reported in the Rural Energy Survey.

OTHRSUP4 consists of one link which is necessary if the rural EMP is run alone but unnecessary if the two models are run together. This link provides ancillary diesel fuel to alcohol manufacture from sugar. That fuel would otherwise be provided by the original EMP.

Evaluation of Results, Issues and Recommendations

The Rural Energy Use Model was installed successfully and can be used as an independent system for rural energy planning at the macro-level.

Computer runs have been conducted and have been found to be satisfactory.

The rural energy model sets up, for the first time in Thailand, a comprehensive, analytical structure linking rural energy demand, supply and conversion technologies. While the structure can be further extended to include direct linkages to sectoral economic models (in order to endogenize the demand projections within the model), in its present form it can be utilized as a useful tool for rural energy sector planning, provided its operating procedures are well understood and its limitations recognized.

This section is devoted to a discussion of the possible applications of the model by NEA staff for analyzing the rural energy sector. The discussion is not designed to be exhaustive, only illustrative. In such a broad area as the rural energy sector, there are many possible applications, not described here, which could be done by NEA staff once they become familiar with operating the model.

Guide to Extended Data Collection Activities

In the rural energy sector, the most obvious and well recognized problem faced by any analytical approach is the relative lack of credible, documented data. It has been stressed at the outset that the main task to be undertaken in this study was not the collection of primary or secondary data for this sector, but rather the organization and categorization of existing data into a coherent structure useful for planning and policy analysis. Surrogate or default values were freely adopted wherever no basic information was available.

However, the model structure does provide a useful guide to an extended data collection activity by providing an indicator of the types of data to be collected, where the major gaps are, and how the data should be structured. In this regard, the information brought out by the 1980 NEA rural survey needs both extension and/or strengthening in the following respects:

- Fuelwood/Charcoal Demand and Supply.

The model distinguishes four types of fuelwood (three of them refer to the distance from which wood is gathered and the fourth to a new source, wood plantations), and three types of charcoal-making. The current allocations of wood and charcoal made to these categories are largely "judgmental guesses" since the data base for allocating them is too meager. The categorization of wood/charcoal supply into these classes is analytically useful since it provides a representation of the cost to society (either direct collection costs or the monetary equivalent of labor time spent in collection) of using wood. It may be useful for future rural energy surveys in Thailand to structure the data gathering procedures to obtain estimates of this breakdown of wood/charcoal use. In order to do this, it would probably be more useful to use purposive sampling techniques directed at uncovering appropriate information from the household population engaged in wood collection/charcoal manufacture rather than the random sampling techniques used in the 1980 survey.

- Fuel Prices

The model calls for delivered prices of different fuels to various consuming sector (households, agricultural production, etc.). Data on fuel prices in rural areas was not collected in the 1980 NEA survey. A new survey should contain questions designed to elicit this information.

- Device Efficiencies

In terms of the model structure, device efficiencies play an important role in the allocation of fuels/choice of technologies for allocating various types of energy forms to different demand sectors. Information on these device efficiencies for existing fuels/technologies, particularly at the point of end use, needs considerable strengthening. A future survey could probably obtain information on these by including an engineer with simple portable measuring equipment as part of the survey team.

- Rural Industry

An important missing element in the current model is rural industry energy consumption data. The types of industries that exist in rural areas and on which no information is available have been listed Section B, the Revised Rural Energy Use Model, above. Future surveys should try to gather information. A link-node structure can then be straightforwardly constructed on the lines done for the other sectors.

- Efficiencies/Costs of New Sources/Technologies

Available information on possible efficiencies and costs of new sources/technologies considered likely for inclusion in the rural energy supply sector is already contained in the current model's data base. NEA should set up an expert group which is capable of monitoring developmerts on this field to make periodic updates of the efficiency/cost information.

Scenario and Policy Analysis

A model of this type is most usefully operated in a scenario fashion to figure out the impacts of different policies or of changed assumptions on costs, prices, efficiencies and market allocations. The model currently contains over 400 links and nodes, each of which is characterized by a set of appropriate number reflecting either data and/or assumptions on demands, supplies, costs, prices, efficiencies and allocations at each node. A change in any one or a set of numbers can come from future policy assumptions (e.g. faster agricultural growth on the demand side, greater availability of LPG on the supply side, etc.), development of technology, or a wide variety of different factors related to increased income, life style, etc. Any change produces a new scenario.

One way to use the model is to construct a set of plausible scenarios incorporating the above (or another set) of developments. Each output of the model will then produce a new energy balance of supply and demand whose implications can be clearly displayed to policy and decision makers.

The limitations of the model, however, need to be understood to limit the possibility of inappropriate decision-making based on its outputs. In an area where the underlying data are "soft," the outputs of LP models need to be interpreted in a normative or scenario fashion, not in a predictive or deterministic sense. Caution should therefore be exercised in ensuring that the model's outputs are not viewed as predictions of what is going to happen, but rather as answers to "what if..." types of questions.

Demand Projection Methodology

The demand projection methodology adopted by the EMP model needs some improvement to include more explanatory variables than just population growth or real GDP. In the household and agricultural production sectors as well as the rural transport sector, fuel prices of petroleum products could be included in the regressions to obtain price elasticities of demand (at least to test whether price is an important variable). Furthermore, in the case of the household sector, rural per capita income and some developmental policy targets (which could be included in the income targets) could be included as additional explanatory variables in the projection method. In the case of rural transport projections, freight transport could include crop production estimates (since a significant part of the major crops are marketed/exported) as an explanatory variable in the regression.

C. THE TRANSPORTATION SUBMODEL

Analysis of Existing EMP Submodels

The transportation subsystem consumed almost 36 percent of the total end-use energy demands in 1977. Its share of petroleum products was approximately 56 percent in the year. Therefore, the transportation subsystem is the largest energy consumer of the Kingdom.

In the EMP model, the transportation subsystem was represented by activities as follows :

- Water Transport
  - Fishery
  - Inland Waterborne
  - International Shipping
- Air Transport
  - Domestic Aviation
  - International Aviation
- Passenger Land Transport
  - Private Car
  - Motorcycle
  - Metropolitan Passenger
    - . BMTA
    - . Mass Transit
    - . Taxi
    - . Tricycle and Minibus
    - . Passenger Trucks
  - Other Urban Passenger
    - . City Buses
    - . Taxi
  - Interurban Passenger
    - . Bus
    - . Rail
- Freight Land Transport
  - Rail
  - Heavy Truck
  - Light Truck

The Revised Transportation Submodel

The transportation Subsystem is considered to be a demand subsystem. The simplest way to develop a demand subsystem is to extract the selected subsystem from the EMP Model. Subsequently, the upstream nodes are linked to node "000" and appropriate shadow prices from the EMP optimization run are assigned to the links.

Flow diagrams representing the transportation subsystem are shown in Fig. 3.12.

Fig. 3.12

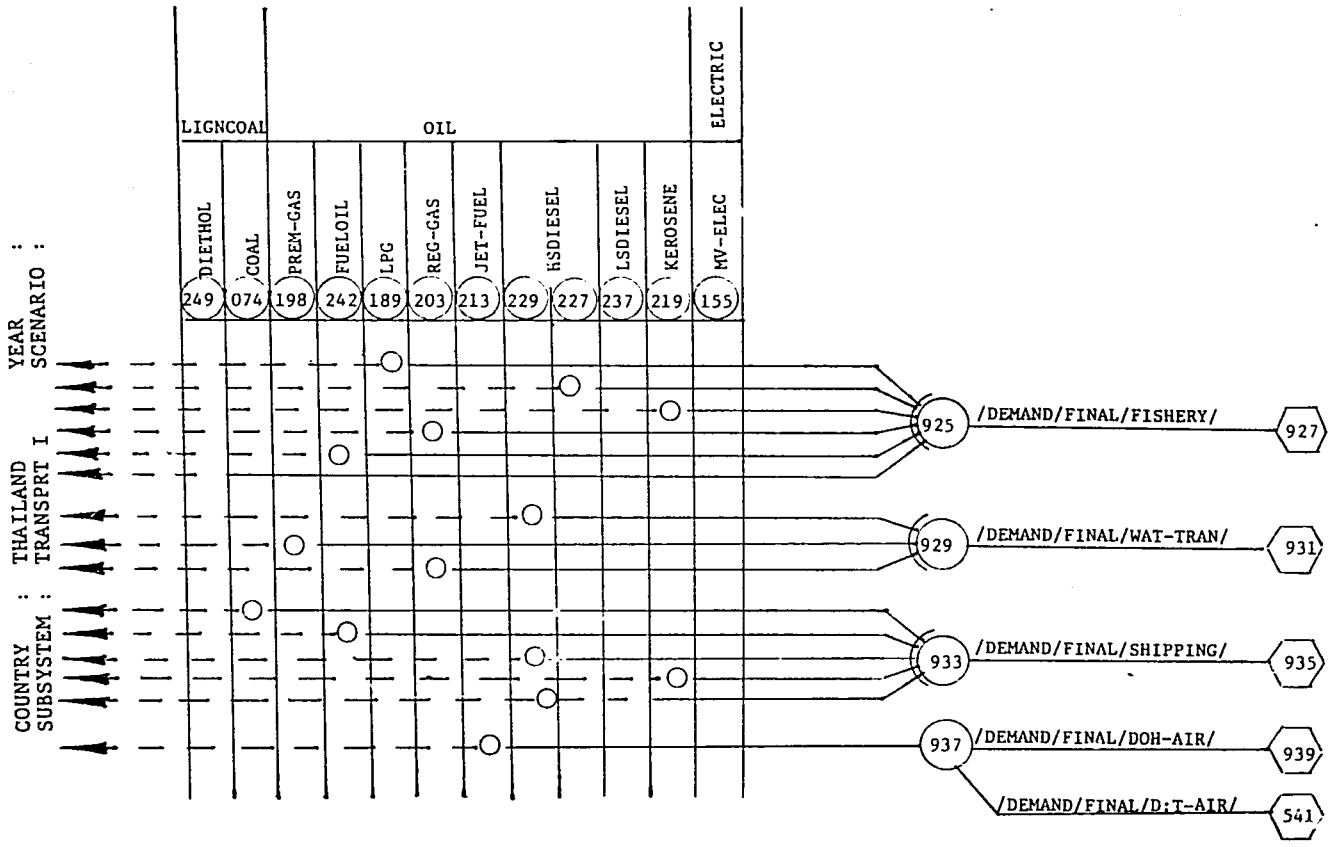

COUNTRY : THAILAND
SUBSYSTEM : TRANSPRT I
YEAR :
SCENARIO :
LIGNCOAL
OIL
ELECTRIC
DIETHOL
COAL
PREM-GAS
FUELOIL
LPG
REG-GAS
JET-FUEL
HSDIESEL
LSDIESEL
KEROSENE
MV-ELEC
249
074
198
242
189
203
213
229
227
237
219
155
925
929
933
937
/DEMAND/FINAL/FISHERY/
/DEMAND/FINAL/WAT-TRAN/
/DEMAND/FINAL/SHIPPING/
/DEMAND/FINAL/DOH-AIR/
/DEMAND/FINAL/D:T-AIR/
927
931
935
939
541

Fig. 3.12 (con't)

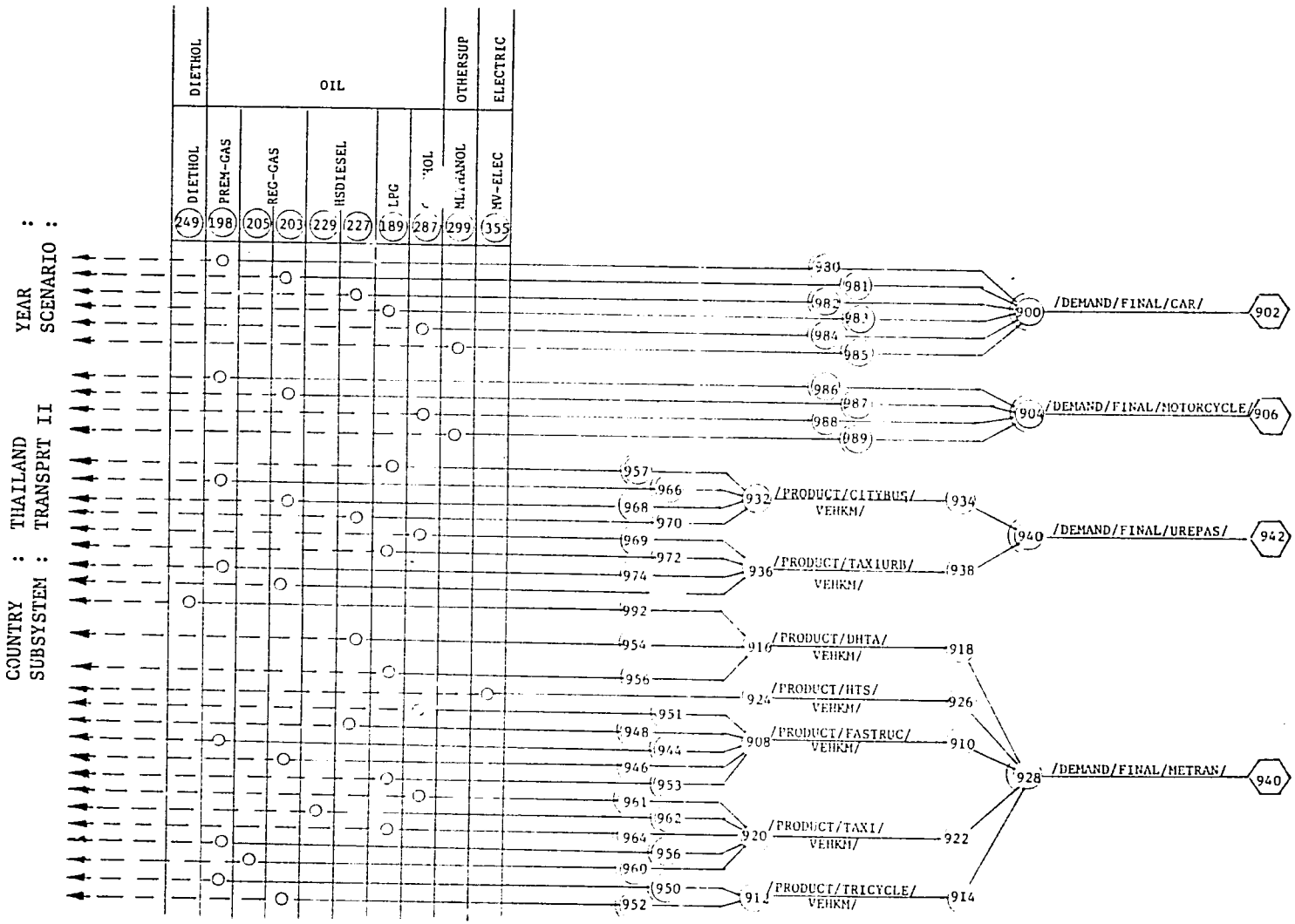

COUNTRY : THAILAND
SUBSYSTEM : TRANSPRT II
YEAR :
SCENARIO :
DIETHOL
OIL
OTHERSUP
ELECTRIC
DIETHOL
PREM-GAS
REG-GAS
HSDIESEL
LPG
MLADANOL
MV-ELEC
249
198
205
203
229
227
189
287
299
355
930
981
982
983
984
985
900
/DEMAND/FINAL/CAR/
902
986
987
988
989
904
/DEMAND/FINAL/MOTORCYCLE/
906
957
966
968
970
969
972
974
932
/PRODUCT/CITYBUS/
VEHKM/
934
940
/DEMAND/FINAL/UREPAS/
942
936
/PRODUCT/TAXIURB/
VEHKM/
938
992
954
910
/PRODUCT/DHTA/
VEHKM/
918
956
924
/PRODUCT/HTS/
VEHKM/
926
951
948
944
946
953
908
/PRODUCT/FASTRUC/
VEHKM/
910
928
/DEMAND/FINAL/METRAN/
940
961
962
964
956
960
920
/PRODUCT/TAXI/
VEHKM/
922
950
952
/PRODUCT/TRICYCLE/
VEHKM/
914

Fig. 3.12 (con't)

COUNTRY : THAILAND YEAR :
SUBSYSTEM : TRANSPRT III SCENARIO :

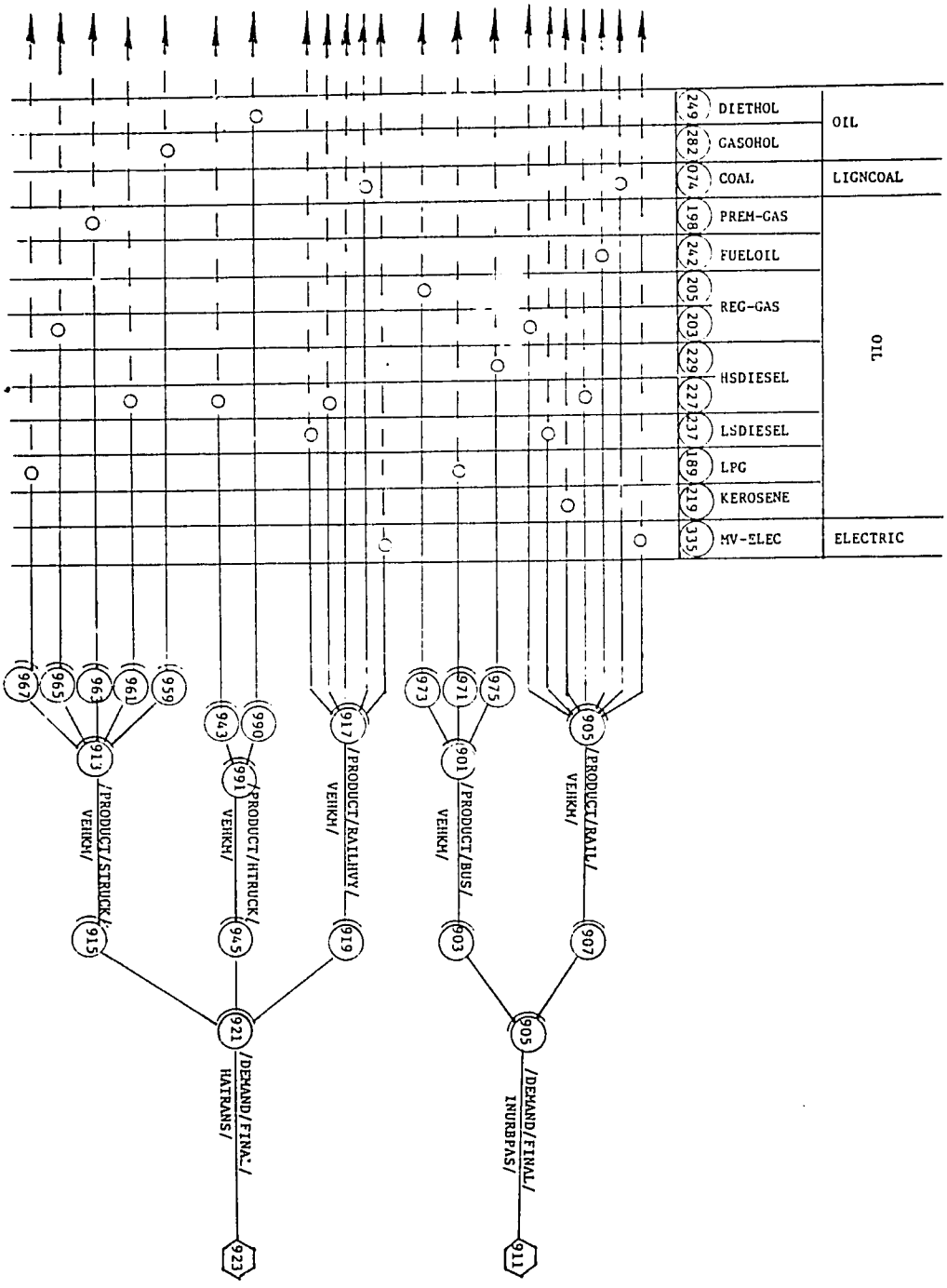
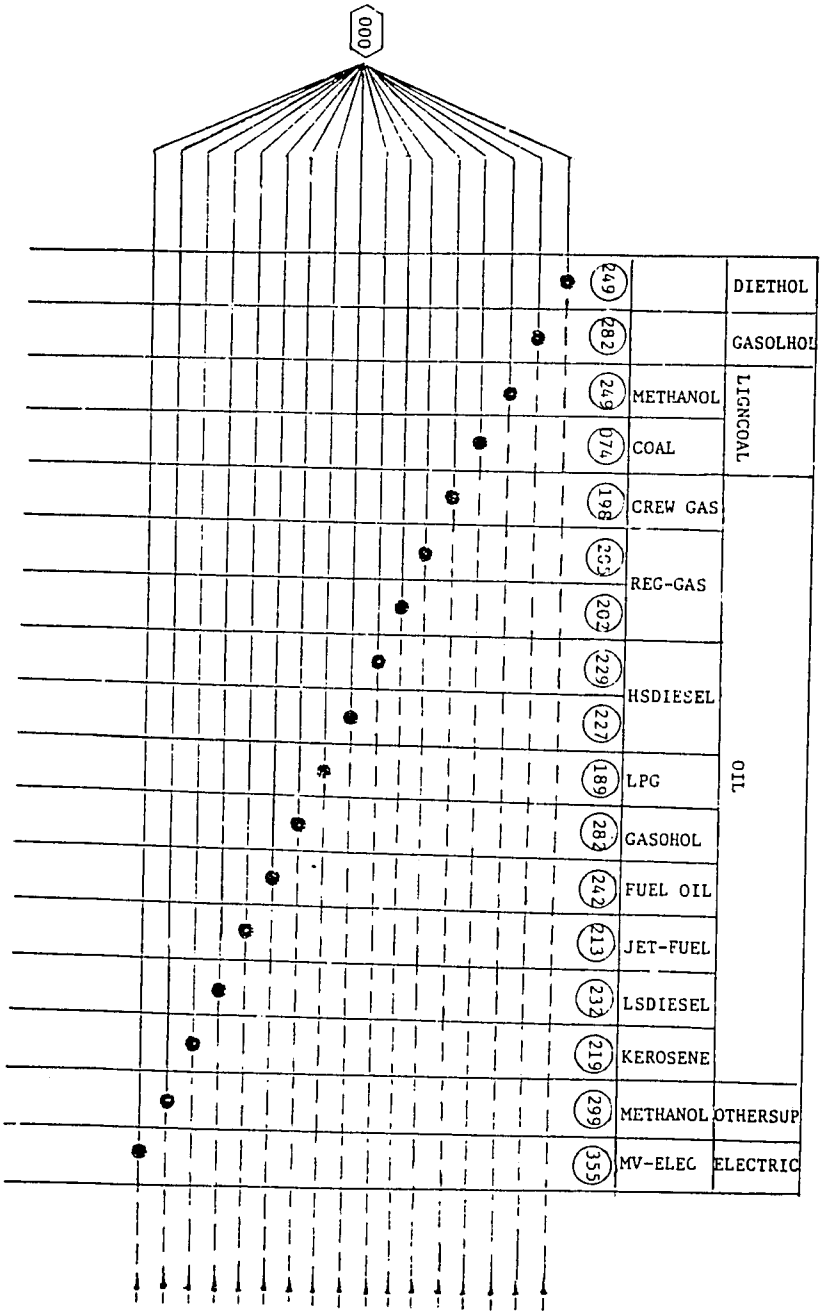


Fig. 3.12 (con't)

COUNTRY : THAILAND YEAR :
SUBSYSTEM : TRANSPORT IV SCENARIO :



The Data Base for Transportation Submodel

As stated in the previous section the transport subsystem itself differs very little from the transportation subsystem in the overall EMP.

How the data base for the transportation subsystem was designed was discussed previously in Section A of this chapter. Please refer to "Techniques and Procedure for Developing a Data base" for an explanation of the overall process of generating EMP submodel data base.

Evaluation of Results

The transportation submodel has been installed successfully and can be used as an independent submodel for transportation energy planning at the macro-level.

Computer runs have been conducted and have been found satisfactory.

Issues and Recommendations

Conceptual Design for the Expansion of the EMP Transportation Submodel

The EMP transportation submodel should be expanded to include:

- The division of transport areas for passenger transport to reflect true characteristics of passenger transport. The area may be divided into metropolitan, urban, towns and small cities, and rural areas (if the rural area is not included in the rural subsector).

- Links that provide possible transport substitutions among transport modes for both passenger and freight transport.

- Links that provide conversion of passenger kilometers to vehicle kilometer. This would require estimated numbers of passenger kilometers per vehicle. Since numbers of passenger kilometers per vehicle may vary (e.g. minimum numbers of passengers per vehicle in some areas are limited according to government regulations), alternative links should be provided.

- Links that provide alternative vehicle kilometers result from changes in the average kilometers per vehicle per year. Such changes may be due to:

  - limited speed,
  - conditions of the road including expressway and highway,
  - restricted zones for some types of vehicles in some areas,
  - allowance of load (e.g. truck)

- ANCILLARY links to fuel which depend on fuel consumption based on alternatives in the above paragraph on alternative vehicle kilometers.

- A link that provides the availability of vehicles to fulfil

transport demands for both passenger and freight transport from source.

- Links that provide alternatives related to energy conservation.

- Alternative links to fuel supply.

A schematic diagram of the conceptual design for the expansion of the EMP transportation subsystem is as shown in Figure 3.13.

Data Bank for the EMP Transportation Subsystem

A discussion of the data bank for the EMP transportation subsystem is detailed below to provide a conceptual guideline for future development. A detailed redesign of the data bank should be made before implementation.

- The Data Bank for the Macro Economic Model

The present transport demand model incorporated into the EMP macro economic model depended on only a few growth factor variables (e.g. real gross domestic product at market prices, disposable income, GDP price deflator, and population).

These variables should remain in the data bank. Data for some variables should be kept by breaking them down into areas (e.g. metropolitan, urban, small city/town, and rural). This requires more effort in collection of data for input into the data bank.

The macro economic model should be revised to provide original demands for area transportation before deriving the demands for transport modes. Since determining the variables requires considerable effort and detailed study, it is not possible at this time to suggest the precise variables required. However, some variables which should be considered for the future revision of the macro economic model may include:

(1) The variables which influence an increase or decrease in traveling such as:

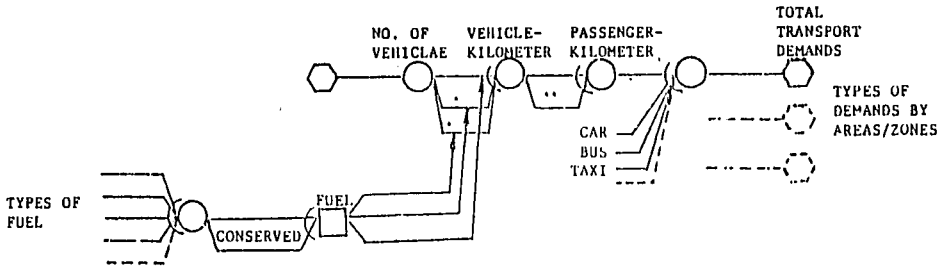
- increase in road distance and condition,

- effects of traffic conditions in communities related to passenger and freight transport (e.g. plans for constructing new expressways, mass transit, revision of traffic system, etc.),

- expansion of a community (such as town planning) which requires more traveling. (This may require considerable effort in follow-up since town expansion in Thailand is difficult to track. Perhaps statistics on increases in individual traveling should be kept instead.),

(2) Information on the behavior of individual transport such as:

Fig 3.13 Schematic Diagram for Modified Transportation Submodel



* Alternative Link for imposed policies, e.g. speed control, restricted area, etc.
** Alternative Link for imposed policies, e.g. minimum number of passenger for some area

- statistics on the purpose of transport demand, taking into account the necessity of the transport required,

- transport preferences mode for specific purposes, taking into account the influencing factors for the preferences,

- frequency of transport required for individual transport demands.

(3) Information concerning the supplementary transportation required by a particular transport mode.

A transport demand and its pattern could be changed due to some influencing factors, such as:

- numbers of telephone lines in service and other types of telecommunication facilities which could reduce transport requirements,

- requirement for another transport mode when a particular transport mode is used (i.e. road transport would be required when railway and water transport modes are used).

- Data Bank for EMP Transportation Submodel

The data/information required for the data bank for the EMP transportation submodel are mostly related to the conversion of flow units. This includes the conversion of:

- total demands to demands for transport modes,

- ratio of passenger-km or freight-km to vehicle-km,

- ratio of vehicle-km to number of vehicles required,

- energy required, per vehicle-km.

Accordingly, data/information to be kept in the data bank should include:

(1) Total demands for transport mode.

This would include data/information such as:

- present demands for transport modes by area,

- cost of transport by mode, and perhaps also, by condition of the vehicle and the infrastructure,

- time required by transport mode,

- statistics on infrastructure availability.

(2) Passenger-km or freight-km to vehicle-km

This includes data/information such as:

- statistics on the number of passengers per vehicle by type of vehicle and area,

- statistics on ton freight-km per vehicle by type of vehicle, and transport zones.

(3) Ratio of vehicle-km to number of vehicles.

This includes data/information such as:

- number of vehicles, by type and area,

- normal vehicle-km or freight-km per vehicle, by type and area,

- normal speed of vehicle, by type and area.

(4) Energy required per vehicle-km.

This includes data/information such as:

- fuel consumption per kilometer by types of vehicles, under conditions relevant to fuel consumption,

- fuel consumption per kilometer under various speeds,

- impact of energy conservation measures to fuel consumption by types of vehicles,

- possibilities of using types of fuels and statistics on the use by types of vehicles.

Sources of Information

Sources of data/information on the transportation subsector are available at several agencies, such as:

- Ministry of Communications
  - Department of Aviation
  - Department of Harbor
  - Department of Highways
  - Land Transport Department
  - Port Authority of Thailand
  - State Railway of Thailand
  - Thai Airways International Ltd.
  - Thai Airways Co., Ltd.
  - Bangkok Mass Transit Authority
  - The Transport Co., Ltd.

- Office of the Prime Minister
  - National Statistical Office

- Ministry of Finance
  - Customs Department

- Ministry of Interior
  - Policy and Plans Office
  - Police Department
  - Expressway and Rapid Transit Authority of Thailand
  - National Housing Authority

- Ministry of Industry
  - Petroleum Authority of Thailand

- Ministry of Science, Technology and Energy
  - National Energy Administration

Tables 3.16 through 3.20 show the existing Transportation Management Information System from the Ministry of Communications.

Transportation Master Plan

A Transportation Master Plan is needed simply because the transportation sector consumed almost 36 percent of the total end-use energy demand in 1977. Its share of petroleum products was about 56 percent in that year. Therefore, the transportation subsystem is the largest energy consumer of the Kingdom. Improved planning and implementation of this sector is crucial for the economic development of Thailand.

A good transportation master plan model and data availability will provide the basis for the transportation subsystem.

D. THE ELECTRICITY SUBMODEL

Analysis of the Existing EMP Electricity Submodel

The existing electricity subsystem can be divided into 3 parts: demands, distribution and transmission, and generation.

In the EMP, demands of electricity depend on the demands from subsystems. Distribution and transmission included in the EMP represent overall national characteristics of the systems which are now operated by MEA, PEA, and EGAT.

Demands

Electricity load is allocated to summer and winter seasons. (This

TABLE : 3.16
MINISTRY OF COMMUNICATIONS' TMIS ROAD TRANSPORT INFORMATION

1. Road Transport Infrastructure
   - 1.1 Length of National and Provincial Highways by Type of Highway, 1970-1979
   - 1.2 Length of National and Provincial Highways by Type of Pavement and by Type of Highway, 1978
   - 1.3 Vehicle-Kilometers on National and Provincial Highways by Type of Pavement and by Type of Highway, 1978
   - 1.4 Length of National Primary and Secondary and Provincial Highways by Type of Cross Section and by Type of Highway, 1978
   - 1.5 Length of National and Provincial Highways by TPU Region and Zone and by Type of Highway, 1978
   - 1.6 Vehicle-Kilometers on National and Provincial Highways by TPU Region and Zone and by Type of Highway, 1978
   - 1.7 Vehicle-Kilometers on National and Provincial Highways by TPU Region and Zone and Type of Highway, 1978

2. Road Transport Fleet
   - 2.1 Number of Registered Vehicles by Year of First Registration and by TPU Vehicle Type, 1978
   - 2.2 Number of Registered Vehicles by TPU Region and Zone and by YPU Vehicle Type, 1978
   - 2.3 Number of Registered Vehicles by TPU Region, Zone and Changwat and by TPU Vehicle Type, 1978
   - 2.4 Number of Registered Vehicles by Bangkok and Non-Bangkok Area and Police Department Vehicle Type and by TPU Vehicle Type, 1978
   - 2.5 Number of Registered Cars and Taxis (4 Wheel) by Bangkok and Non-Bangkok Area and by Curb Weight, 1978
   - 2.6 Number of Registered Buses by Tvpe of Service and Bangkok and Non-Bangkok Area And by Curb Weight, 1978
   - 2.7 Number of Registered Tracks by Type of Use and Bangkok and Non-Bangkok Area and by Curb Weight, 1978
   - 2.8 Number of Registered Trucks by Type of Use and Bangkok and Non-Bangkok Area and by Curb Weight, 1978
   - 2.9 Number of Registered Truck Tractors, 4 Trailers and Semi-Trailers by Bangkok and Non-Bangkok Area and by Curb Weight, 1978

3. Road Transport Flows

- 3.1 Tons and Ton-Kilometers Transported by Major Commodity Group, 1977-1978
- 3.2 Tons and Ton-Kilometers Transported by Origin and by Destination Region, 1978
- 3.3 Tonnage Transported by Origin and by Destination Region/TPU Zone, 1978
- 3.4 Ton-Kilometers Transported by Origin and by Destination Region/TPU Zone, 1978
- 3.5 Tonnage Transported by Major Commodity Group and Origin and by Destination Region, 1978
- 3.6 Ton-Kilometers Transported by Major Commodity Group and Origin and by Destination Region, 1978

TABLE : 3.17
MINISTRY OF COMMUNICATION'S TMIS RAIL TRANSPORT INFORMATION

---

1. Rail Transport Flows

- 1.1 Carload Tons and Ton-Kilometers by Major Commodity Group, 1978-1981(CY)
- 1.2 Carload Tons and Ton-Kilometers by Origin and by Destination Region, 1981(CY)
- 1.3 Carload Tonnage Transported by Origin and by Destination Region/TPU Zone, 1981(CY)
- 1.4 Carload Ton-Kilometers Transported by Origin and by Destination Region/TPU Zone, 1981(CY)
- 1.5 Carload Tons Transported by Major Commodity Group and Origin and by Destination Region, 1981(CY)
- 1.6 Carload Ton-Kilometers by Major Commodity Group and Origin and by Destination Region, 1981(CY)

TABLE : 3.18
MINISTRY OF COMMUNICATIONS' TMIS INLAND WATERWAYS AND COASTAL TRANSPORT INFORMATION

1. Water Transport Fleet
   - 1.1 Number and Gross Tonnage of Registered River Vessels, 1978-1981
   - 1.2 Number and Gross Tonnage of Registered Number and Gross Tonnage of Registered Seagoing Vessels, 1978-1981

2. Inland Waterways Flows
   - 2.1 Freight Tonnage by Major Commodity Group and by year, 1976-1977
   - 2.2 Tons and Ton-Kilometers by Origin and by Destination Region, 1977
   - 2.3 Tonnage Transported by TPU Commodity Group and Origin and by Destination Region/TPU Zone, 1977
   - 2.4 Ton-Kilometers Transported by TPU Commodity Group and Origin and by Destination Region/TPU Zone, 1977
   - 2.5 Ton Transported by Major Commodity Group and Origin Region and Destination Region, 1977
   - 2.6 Ton-Kilometers Transported by Major Commodity Group and Origin Region And by Destination Region, 1977

3. Coastal Transport Flows
   - 3.1 Tonnage of Freight Traffic through 18 Coastal Ports, 1977-1979
   - 3.2 Tonnage of Freight Traffic through 18 Coastal Ports by Port and by TPU Commodity Group. 1977-1979
   - 3.3 Inbound Tonnage of Freight Traffic through 18 Coastal Ports by Port and by TPU Commodity Group, 1979
   - 3.4 Outbound Tonnage of Freight Traffic through 18 Coastal Ports by Port and by TPU Commodity Group, 1979

TABLE : 3.19
MINISTRY OF COMMUNICATIONS' TMIS AIR TRANSPORT INFORMATION

1. Air Transport Fleet
   1.1 Thailand's Fleet of Aircraft, as of December 31, 1981

2. Air Transport Flows
   2.1 Air Traffic by Airports, 1977-1981
   2.2 Freight Tons and Ton-Kilometers Transported by Origin and Destination Region/TPU Zone, 1981
   2.3 Freight Tonnage Transported by Origin and Destination Region/TPU Zone, 1981
   2.4 Freight Ton-Kilometers Transported by Origin and by Destination Region/TPU Zone, 1981

TABLE : 3.20
MINISTRY OF COMMUNICATIONS' TMIS INTERNATIONAL TRANSPORT INFORMATION

1. Shipping Fleet
   1.1 Thai Flag Merchant Fleet by Vessel Type, Age of Vessel and DWT, 1981

2. Shipping Flows
   2.1 Foreign Vessels Called at Port of Bangkok by Registered Tonnage, 1979-1981
   2.2 Foreign Vessels Called at Port of Bangkok by Flag of Vessel, 1979-1981
   2.3 Inbound Foreign Vessels Called at Port of Bangkok by Flag of Vessel, 1979-1981
   2.4 Outbound Foreign Vessels Called at Port of Bangkok by Flag of Vessel, 1979-1981
   2.5 Inbound Foreign Vessels Called At Port of Bangkok by Port of Arrival, 1979-1981
   2.6 Outbound Foreign Vessels Called at Port of Bangkok by Port of Departure, 1979-1981

3. Foreign Trade Flows
   3.1 Value and Weight of Commodity Exported by Commodity by Chapter and by Mode of Transport, 1981
   3.2 Value and Weight of Commodity Imported by Commodity by Chapter and by Mode of Transport, 1981

categorization is certainly too rough). A default value for the summer percentage is set at 0.52 and the percentage is applied to all industries, except soda ash. Typically, an industry's load between summer and winter varies. The allocation of load between summer and winter should be reviewed and kept up to date to represent the real load characteristics of industrial types incorporated in the study. The same is also true of load factors and load factor multipliers.

Distribution and Transmission

In the EMP, a distribution system is represented by one link. This may be due to the limitation on numbers of links. In fact, distribution system parameters (e.g. investment cost, loss, etc.) are difrerent in different areas (specifically in metropolitan and rural areas). There should be more than one link to represent the distribution system. Perhaps, there should be one for each load center.

Similar to the distribution system, the transmission system is represented by one link. This limits the representation of the transmission system which transmits power from generating sources to load centers. There should be more than one link to represent the transmission system for the transmission of electricity from generating sources to load centers.

In the EMP, the distribution system is classified into only medium and low voltage. This does not represent the true voltage levels of the present distribution system. Voltage levels of the distribution system should be reclassified. Further, the medium voltage distribution system should be stepped down to low voltage distribution. This would require a link for low voltage level to medium voltage level, not from a single node as in the EMP model.

The linkage between the micro-hydro to the distribution system is represented by one link. This may not be true in cases where limited numbers of villages in a rural area could be supplied by a micro-hydro. There should be a separate link between micro-hydro to the villages in rural areas supplied by micro-hydro.

Distance and load density may change the characteristics of the distribution system (specifically, the cost of investment which would vary depending on the distance and load density). The effect of distance and load density should be incorporated into the distribution system.

The purchase price for imported electricity is set without taking into account that the price of electricity should be broken down into 2 components--demand and energy.

The EMP system should provide the possibility to differentiate between imported prices for both the demand and energy components.

Analysis of the Revised EMP Electricity Submodel

The electricity subsystem is a conversion subsystem. Having extracted the selected subsystem from the EMP model, the downstream nodes of this subsystem are supply nodes for demand from other subsystems. These nodes

would be linked to other demand subsystems employing existing links to upstream nodes of demand subsystems in the EMP model. The flows of end-used electricity at these nodes could assigned.

Moreover, the upstream node of the electricity subsystem will be linked to node "000". Appropriate shadow prices from the EMP optimization run would be assigned to the links.

It should be noted that creation of supply nodes for 'ANCILLARY' parameters and demand nodes for the 'BY-PRODUCT' parameters as discussed previously are also needed.

Flow diagrams representing the electricity subsystem are shown in Figs. 3.14-3.18.

Data Base for Electricity Subsystem

As stated in the previous section, the electricity subsystem itself differs very little from the electricity subsystem in the overall EMP.

How the data base for the electricity subsystem was designed was discussed previously in Section A of this Chapter. Please refer to "Techniques and Procedures for Developing Data Bases" for an explanation of the overall process of generating EMP submodel data bases.

Evaluation of Results

The electricity submodel has been installed successfully and can be used as an independent submodel for electricity energy planning at the macro-level.

Computer runs have been conducted and have been found satisfactory.

Issues and Recommendations

Conceptual Design for the Expansion of EMP Electricity Submodel

The EMP electricity submodel should be expanded to include:

- The division of the load center by geographical area including the metropolitan area. For each load center in provincial areas, the expansion should include the addition of distribution links to represent major characteristics of the distribution system in the area, for example:

  - to reclassify voltage levels to represent the present distribution system,

  - to incorporate the effects of distance and load density according to load characteristics (e.g. household density, Kwh/capita, and numbers of meter per distribution length) which would reflect the true load characteristics of the distribution system for the electricity submodel.

Fig. 3.14

COUNTRY : THAILAND YEAR :

SUBSYSTEM : ELECTRIC SCENARIO :

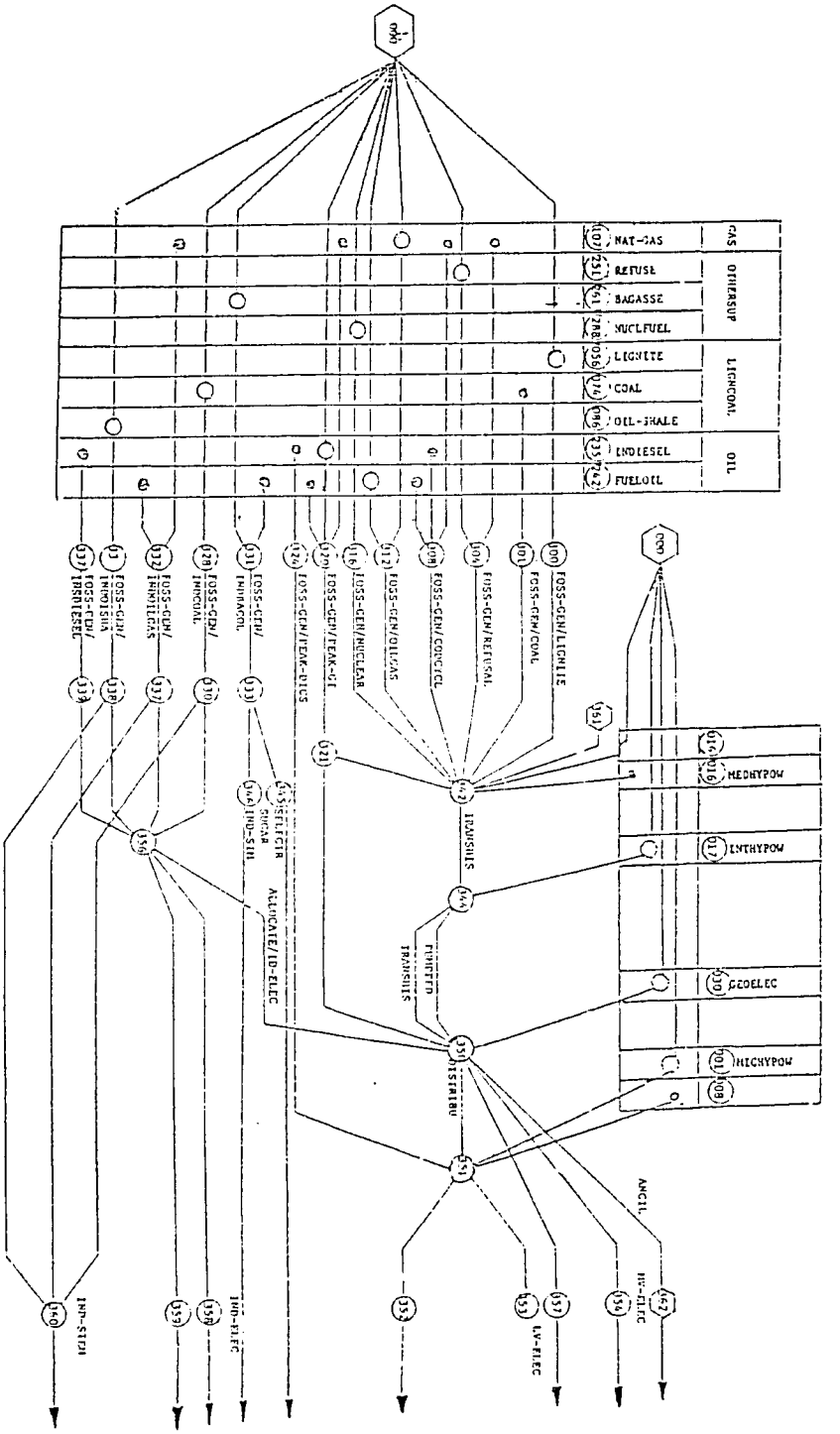


Fig. 3.15 Electricity Scenario

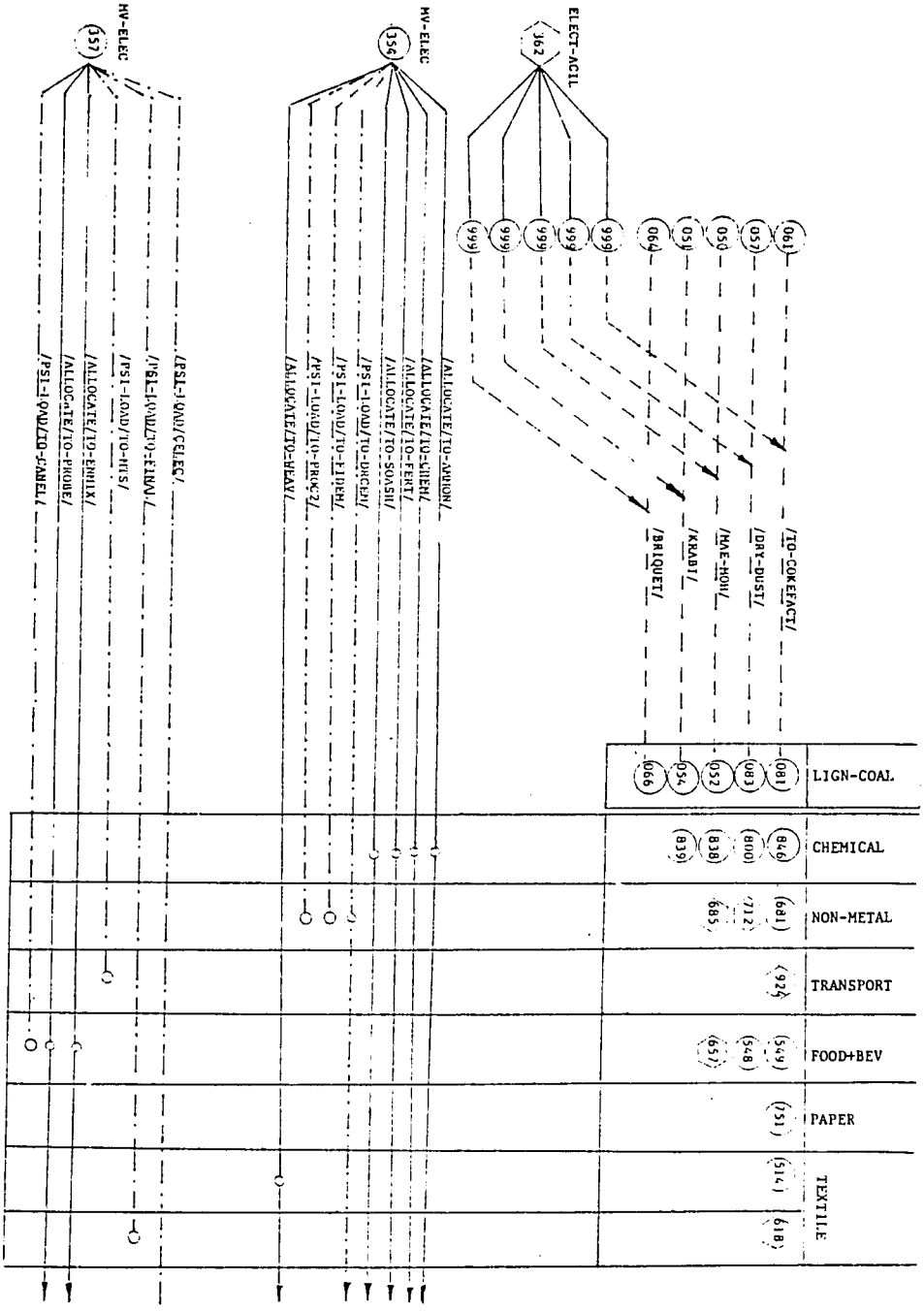


Fig. 3.16 Electricity Scenario

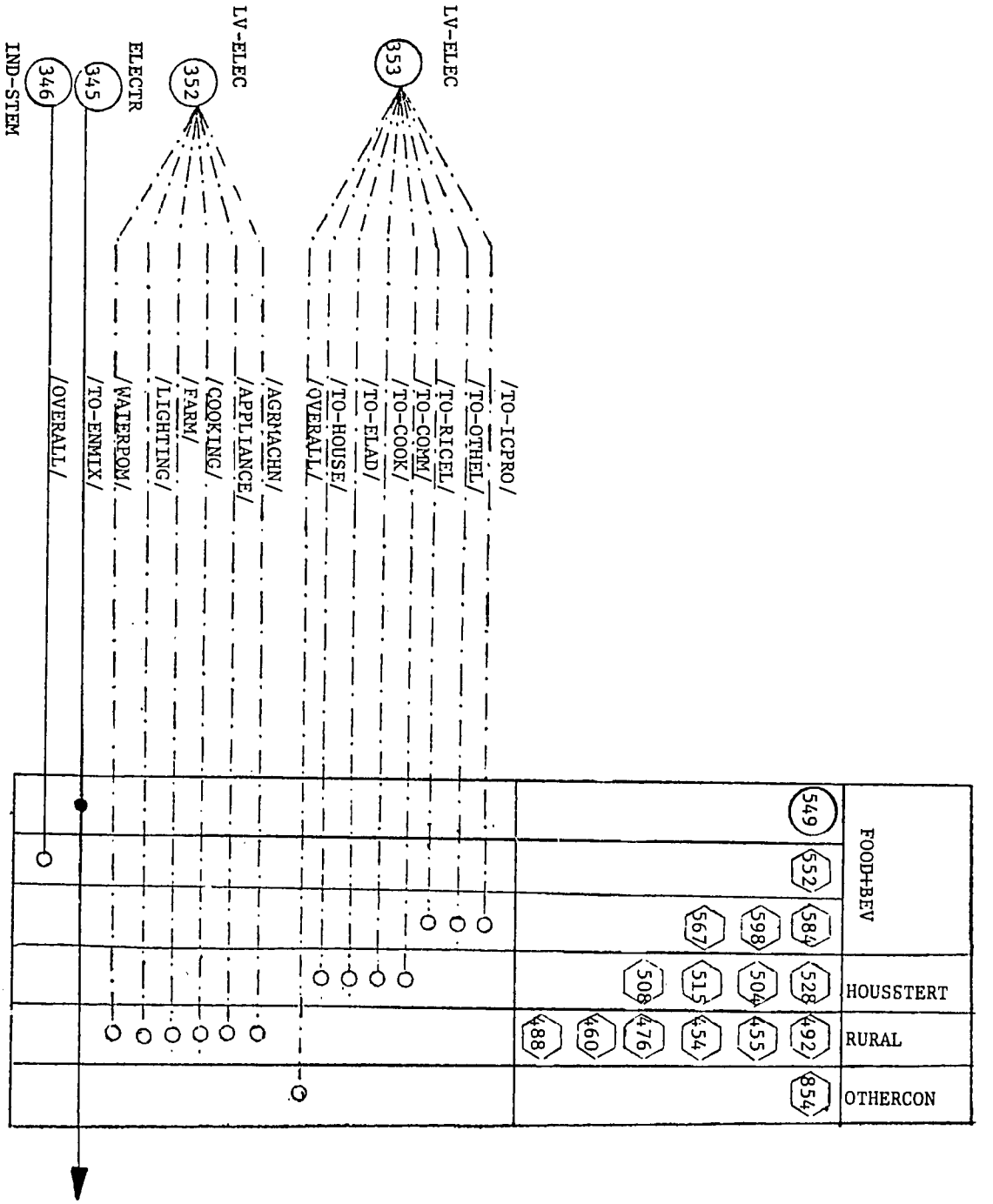


Fig. 3.17 Electricity Scenario

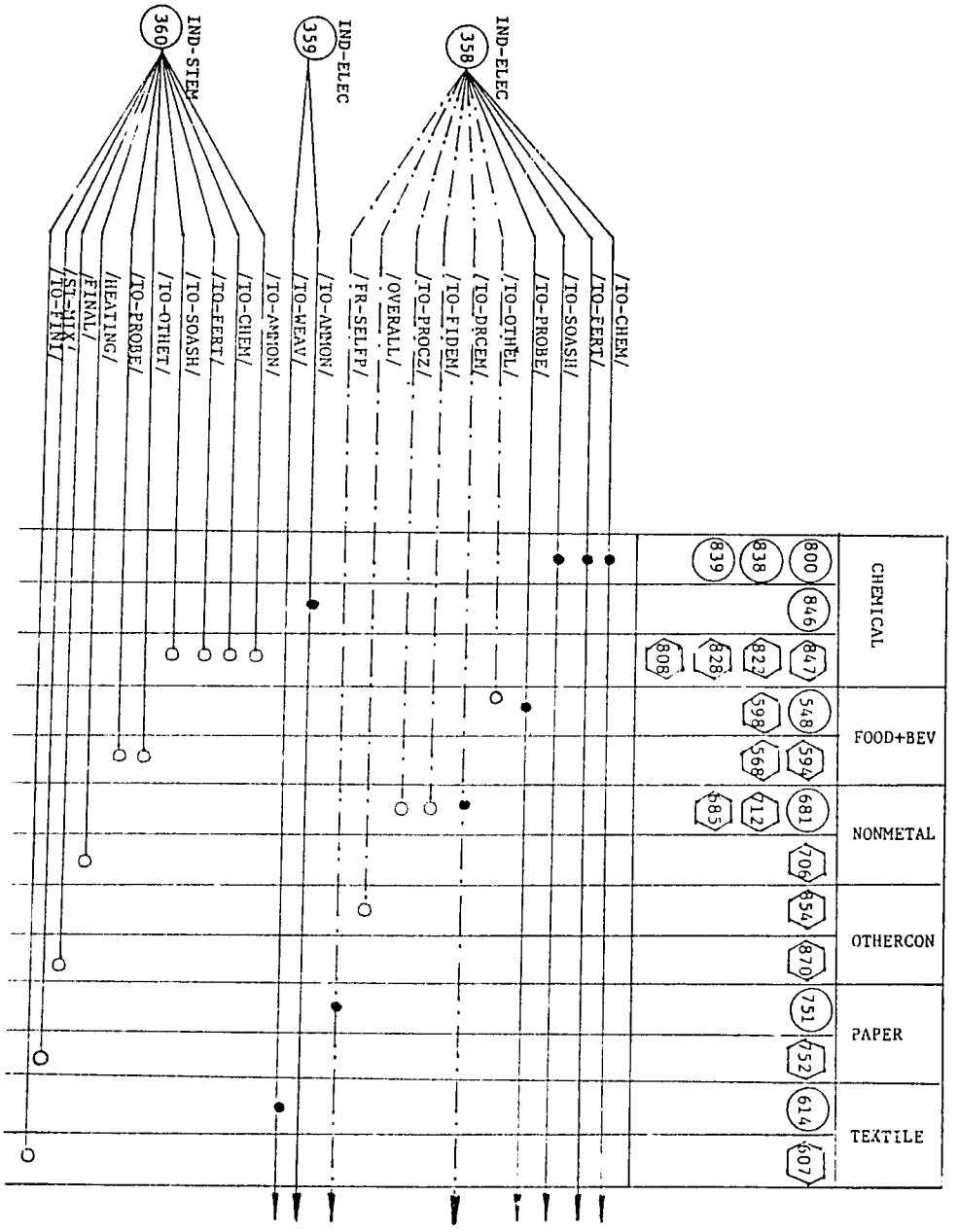
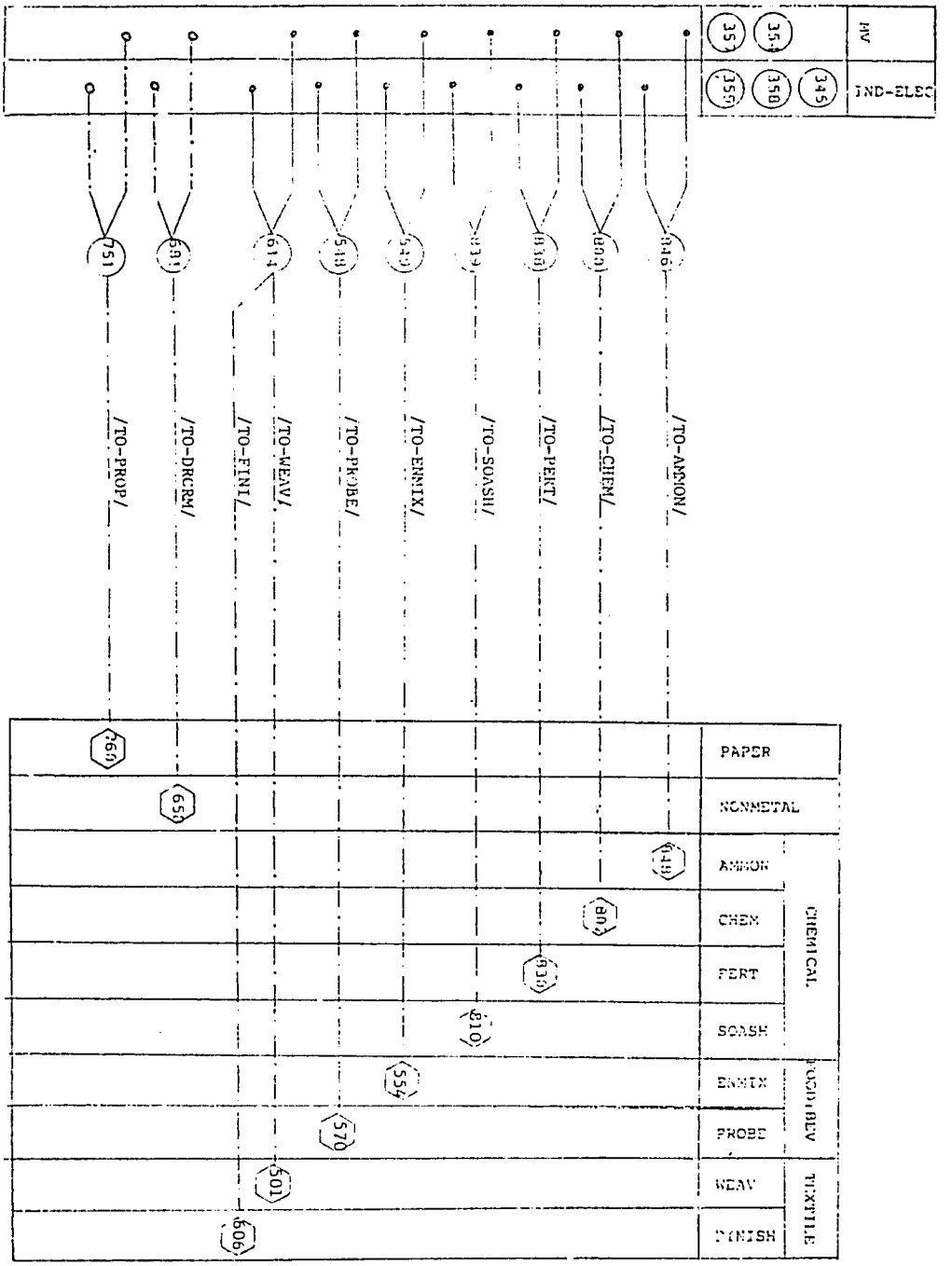


Fig. 3.18 Textile Scenario



- The division of the load center would be useful for the assessment of the expansion of the distribution system specifically to the rural areas.

- The division of electricity generating zones taking into account locations of EGAT major power plants. This will separate the generating characteristics to provide more details of generating plants by types and sizes in the study.

- The addition of more transmission links to replace the present, single transmission link. Perhaps, there should be a link between each generating zone and each load center providing that such a link exists in the EGAT system.

- The addition of a rural demand node to represent the rural communities that could be served by a mini/micro-hydro plant. This would allow a potential assessment of impact of the mini/micro-hydro plant contributed to the national development (e.g. total energy cost, foreign currency saving, etc.).

The expansion of the electricity subsystem would provide a means for determining parameters to be used in the integrated EMP model.

Data Bank for the Electricity Submodel

A discussion on the data bank development for the EMP electricity submodel is detailed in this subsection to provide a conceptual guideline for future development. A detailed design of the data bank should be made before implementation.

- Load Demands

Statistics on load demands of electricity for types of demands (including types of demands of industries) should be kept in the data bank. Units of load demands should be in terms of Kwh per unit, e.g. Kwh per capita for residential users, Kwh per product output for industries. These statistics should be classified by voltage levels and by major activity types of the demands, where appropriate.

- Load Percentage of Demand Types

Since the EMP requires the percentage of the yearly load consumed during summer and winter hours, load percentages should be kept in the data bank by types of demands as well as by voltage levels and by major activities as classified by load demand types.

It should be noted that statistics on load percentages kept must be consistent with the summer hours desired for the EMP. Therefore, the numbers of hours of seasons should be decided first.

It seems that the division of loads for the summer and winter seasons may not be required for Thailand. In the EMP, one may assume that summer hours would cover 364 days a year and the remaining one day a year would be for winter. This would take much less effort in

gathering data for the data bank. However, this requires further investigation.

- Load Factors of Demand Types

Load factors for load types for both the summer and winter seasons are required for the EMP. The statistics should be also kept in the data bank by type of demands as well as by voltage levels and by major activities as classified by load demand types.

Load factors for types of demands may vary monthly or seasonally. Therefore, load factors for each type of demand should be kept in accordance to the variations. Perhaps, load factors should be kept monthly in order that average annual load factors for each demand type could be determined.

- Load Factor Multiplier of Demand Types

By definition, load factor multipliers for the summer and winter seasons are the ratio of the highest hourly system load during the season to the highest hourly load observed during the season in the system's peak hours. Accordingly, a system load curve including monthly system peak hours should be kept in the data bank.

The highest hourly load in the system's peak hours of each demand type may be difficult to collect. If the data are not available, approximate peak hours of each demand type may be determined from its monthly load factor and the monthly load. The approximate peak hours of demand types could be summed up and adjusted to be equal to the system's peak hours.

- Characteristics of Distribution and Transmission System

Circuit length of the distribution and transmission system by major categories and their engineering characteristics should be kept in the data bank.

In the EMP model, investment costs of distribution and transmission systems are expressed in terms of dollars per kilowatt. This causes a difficulty in estimating the system investment cost since it would vary depending on the construction programs in each year. An alternative solution to this problem is to keep annual statistics on investment per circuit length of each system category to be used as a basis in projection of the future investment cost for an initial run. The cost may be readjusted after the optimized results are obtained.

Other cost components to be kept are the fixed and variable costs of the distribution and transmission system by categories. The statistics of the costs may be kept similar to the investment cost.

System loss is another parameter required for the EMP model. Accordingly, the loss should be kept for each system category. Another parameter required, for which statistics should be kept in the data

bank, is the availability of the system of each category.

- Characteristics of the Generating System

Records of all types of generating systems should be kept in the data bank including their general engineering characteristics.

Installed generating capacity, annual peak, and energy generation of each system category should be maintained in the data bank. Load and plant factors should be compiled. Fuel requirements per unit of output are also a major data item to be kept for the EMP model.

Typically, the availability of an electric power generating system is expressed in terms of maintenance rate and forced outage rate. Therefore, such figures should be kept in the data bank.

- Sources of data/information

Data/information for the electricity subsystem would be available from reports of electricity-related agencies such as EGAT, MEA, and PEA. However, considerable efforts are required to make direct contact with such agencies to obtain complete and accurate data/information.

Data/information may not be available from government agencies. In this case, surveys should be conducted to collect the data/information. The surveys would include visits to industrial plants.

System Cost Minimization of Electricity's Capacity and the Transmission Expansion Model.

This kind of model should be developed for sectoral electricity planning. It would be essentially a linear programming model for planning electrical capacity and transmission expansion.

A good electricity sectoral planning model will help with the modeling of an electricity subsystem. If enough acurate data are also available, the electricity subsystem would be an invaluable tool for planning.

E. THE TEXTILE INDUSTRY SUBMODEL

Analysis of the Existing EMP Model

In the EMP model, the textile industry is divided into 3 major processes:

1. Raw textile processing,

2. Finished textile processing (bleaching, dyeing, and sizing),
3. Other heat and power demands for fabrication.

All textile industry activities are not included in the existing EMP since it included only weaving (and perhaps, also spinning), finishing, and fabrication. Major activities of the textile industry should include:

- Ginning
- Spinning
- Weaving
- Knitting
- Finishing
- Garment
- Man-made Fiber
- Scine & Net
- Textyrize Yarn
- Blanket
- Sock

Based on statistics kept by the Thai Textile Manufacturing Association and the Thai Weaving Industry Association, woven fabrics were estimated at 1,178 million sq. yards in 1977 and increased to 1,387 million sq. yards in 1988. The estimated figures used in the EMP somehow were different.

It should be noted that some activities missing or unseparated in the EMP model consume significant energy. For example, production of yarns in 1977 was estimated to be 182,136 tons. This activity consumed energy (such as electricity) different from that consumed by weaving.

The Revised Textile Submodel

Industry systems include a group of subsystems--textile, paper. non-metallic, food and beverage, chemical and other industries. All industries could have been included in a single submodel, but due to time limitations, only the textile and paper subsystems were chosen for detailed study.

Figs. 3.19-3.25 show all the industry subsystems.

The textile subsystem is considered as a demand subsystem. The simplest way to develop a demand subsystem is to extract the selected subsystem from the EMP model. Subsequently, the upstream nodes are linked to node "000" and appropriate shadow prices from the EMP optimization run are assigned to these links (see Fig. 3.19).

The Data Base for the Textile Submodel

As stated in the previous section, the textile subsystem itself differs very little from the textile subsystem in the overall EMP.

How the data base for the textile subsystem was designed was discussed previously in Section A of this Chapter. Please refer to "Techniques and Procedures for Developing Data Bases" for an explanation of the overall process of generating EMP submodel data bases.

Fig. 3.19 Industry Subsystem Flow Diagram

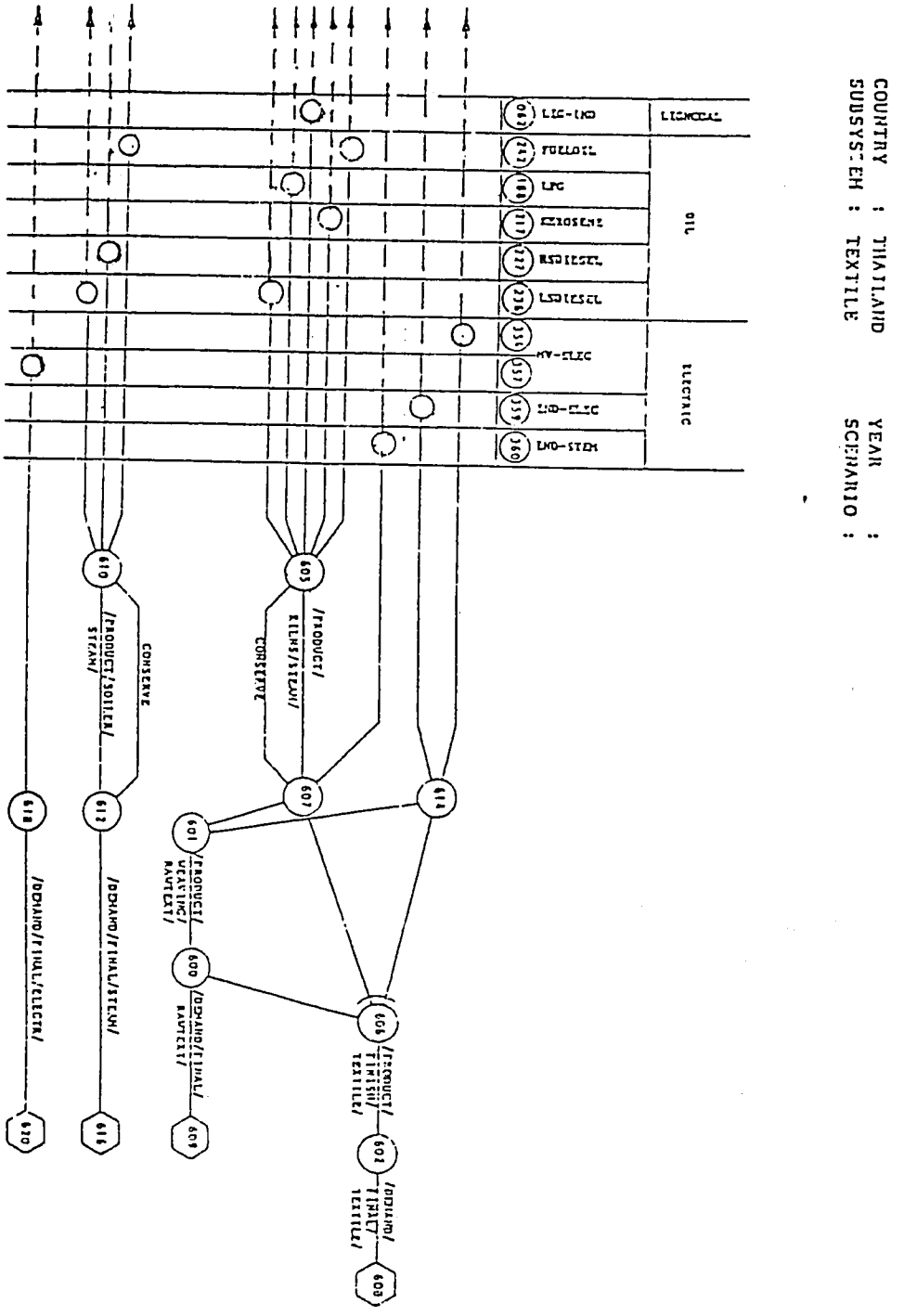


Fig. 3.20

COUNTRY : THAILAND YEAR :
SUBSYSTEM : PAPER SCENARIO :

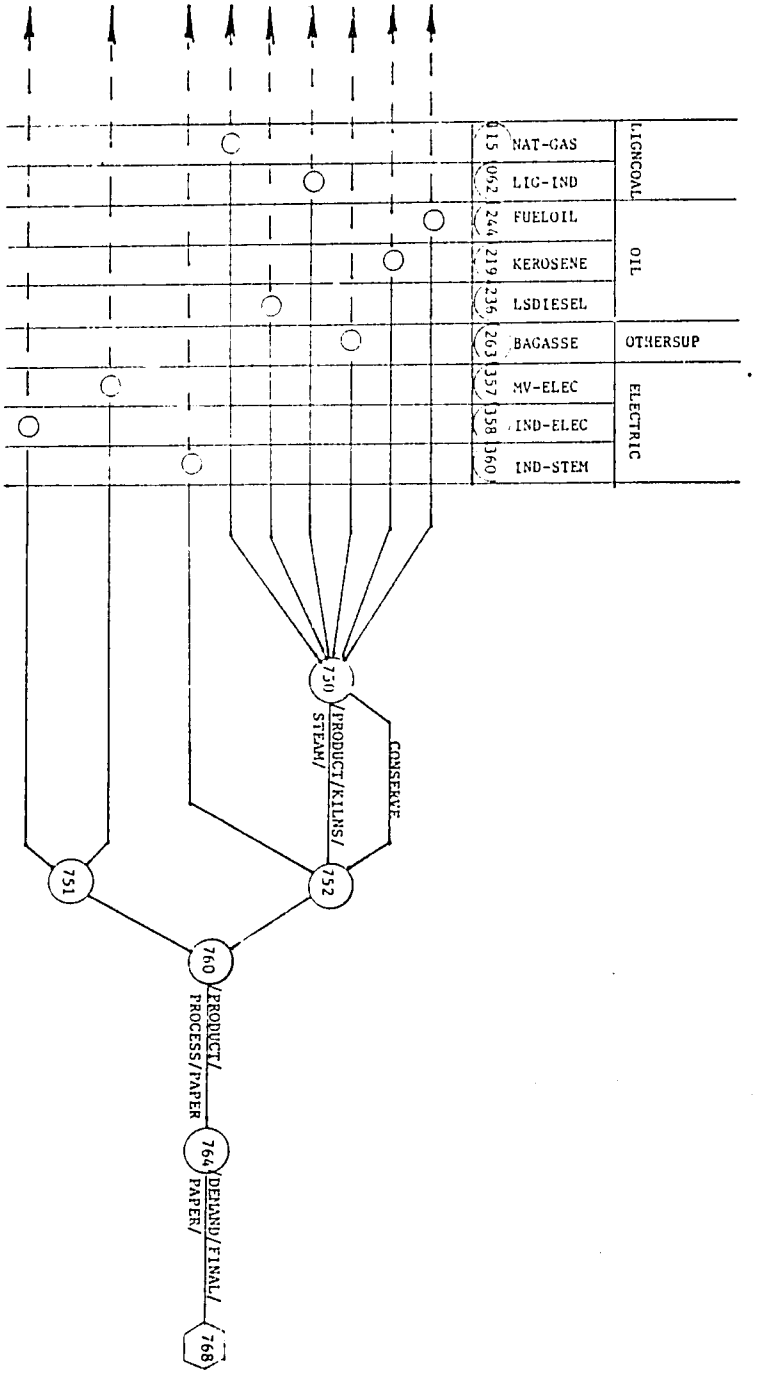


Fig. 3.21

COUNTRY : THAILAND YEAR :
SCENARTO :
SUBSYSTEM : NON-METAL

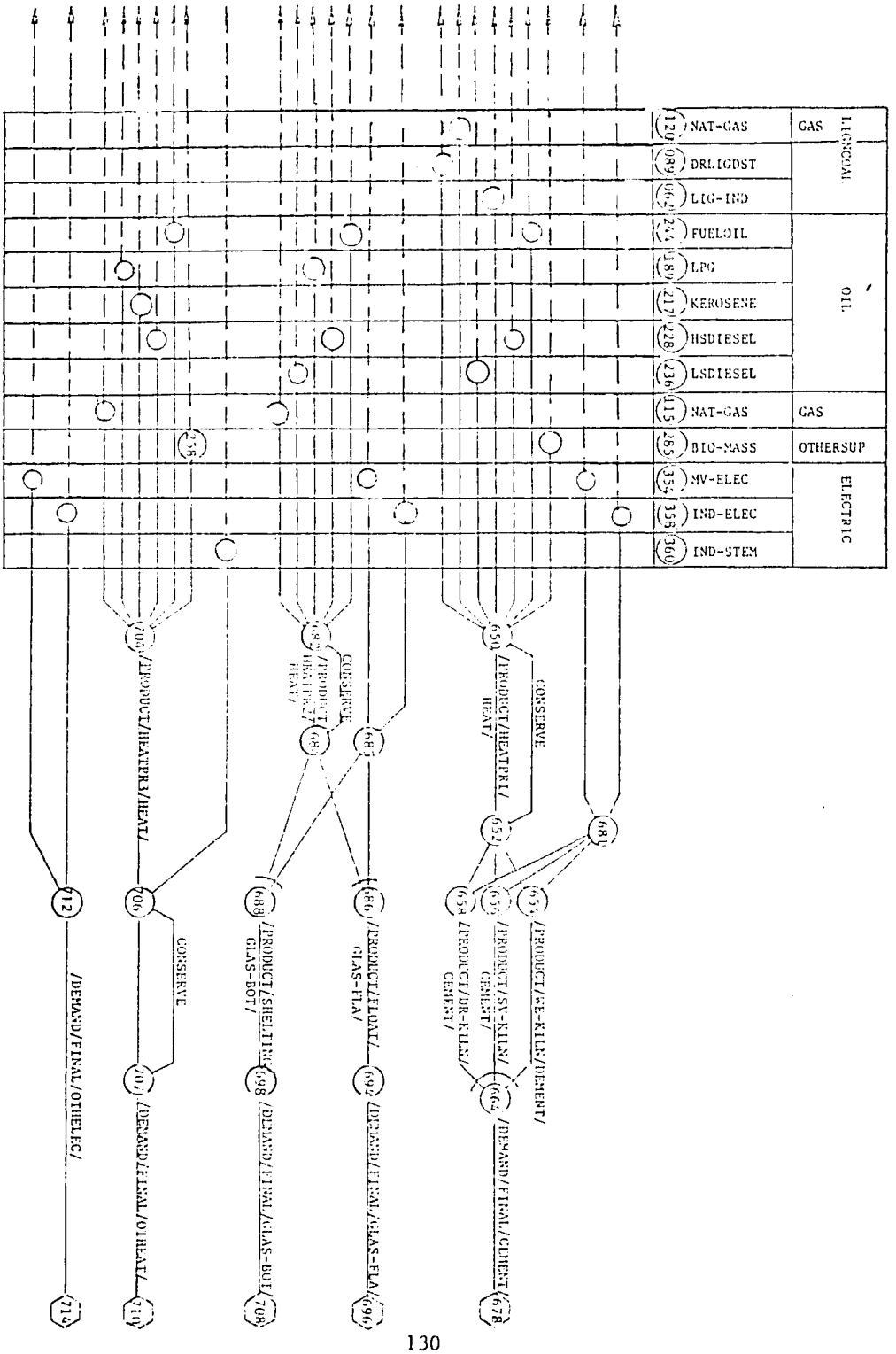


Fig. 3.22

COUNTRY : THAILAND YEAR :

SUBSYSTEM : FOOD + BEV SCENARTO :

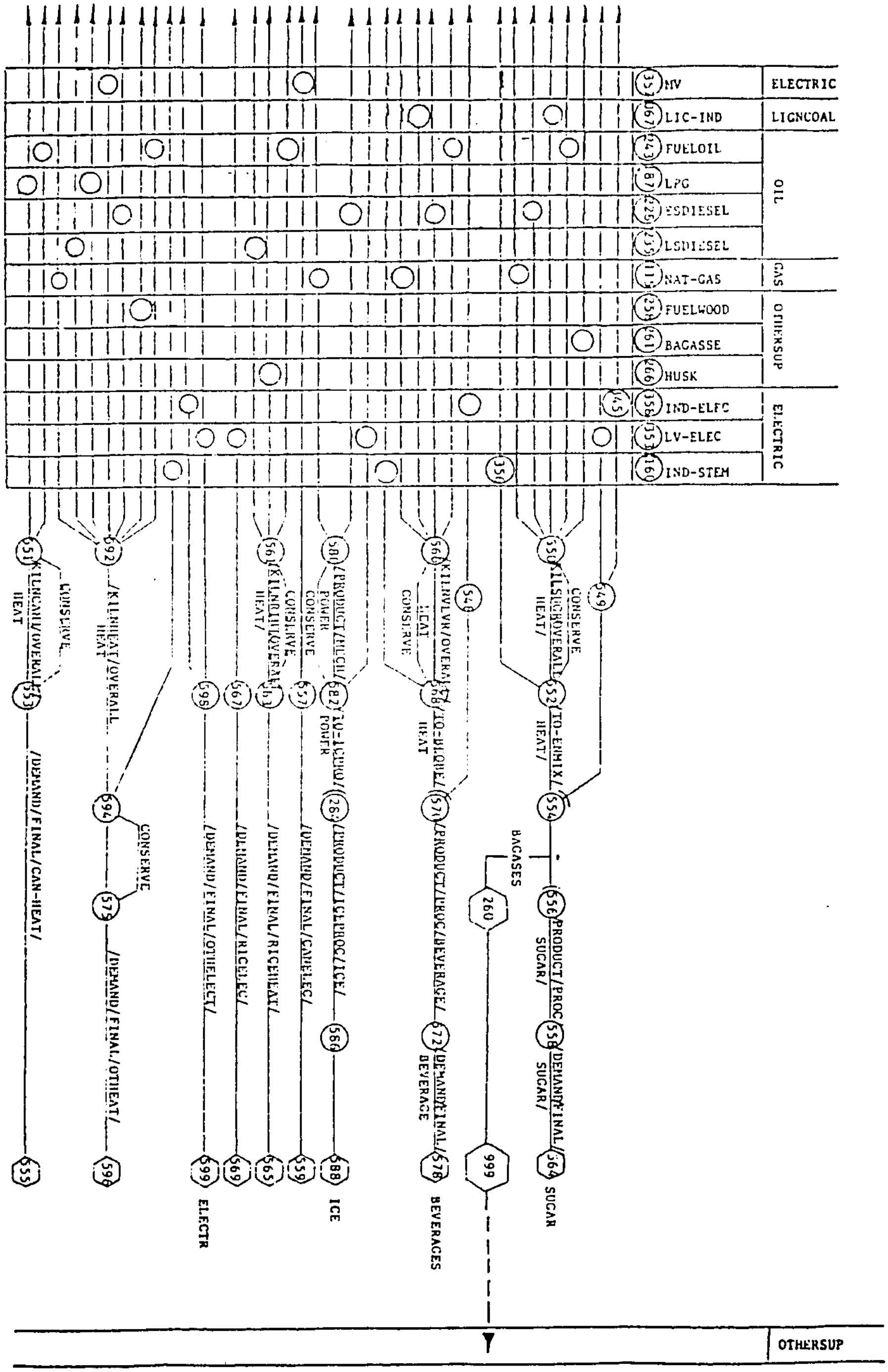


Fig. 3.23

COUNTRY : THAILAND YEAR :
SUBSYSTEM : CHEMICAL SCENARIO :

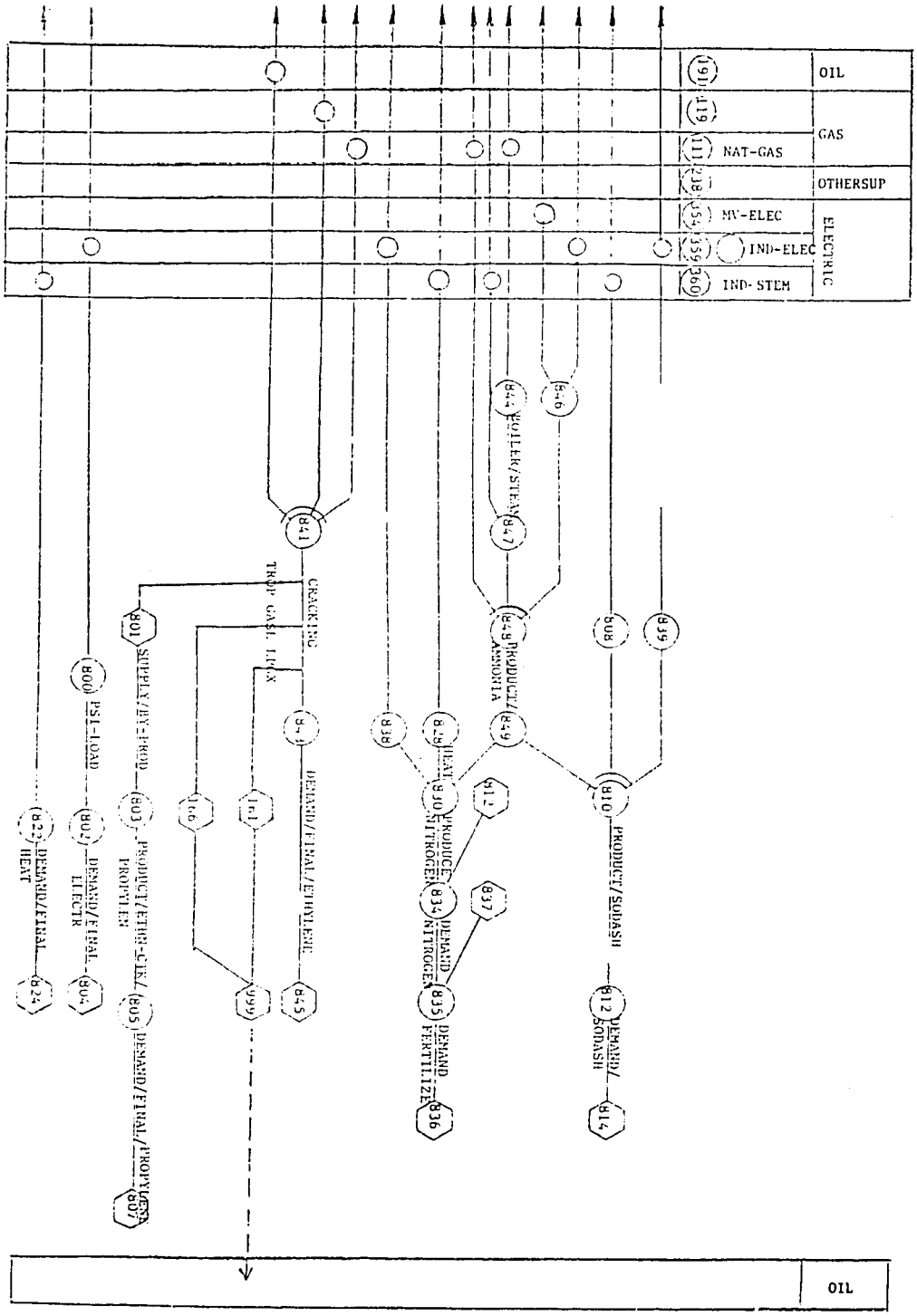


Fig. 3.24

COUNTRY : THAILAND YEAR :
SUBSYSTEM : OTHERCON SCENARIO :

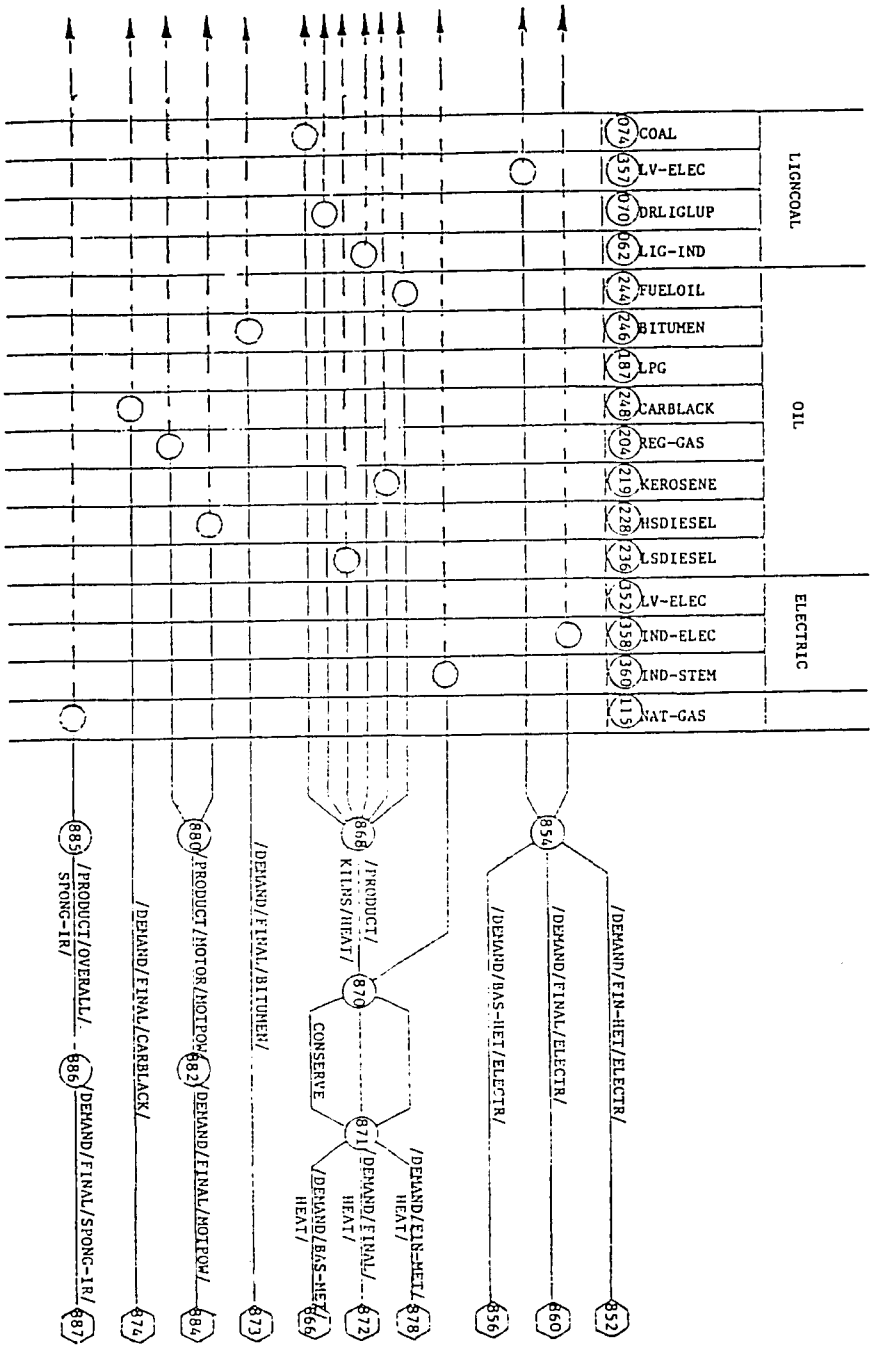
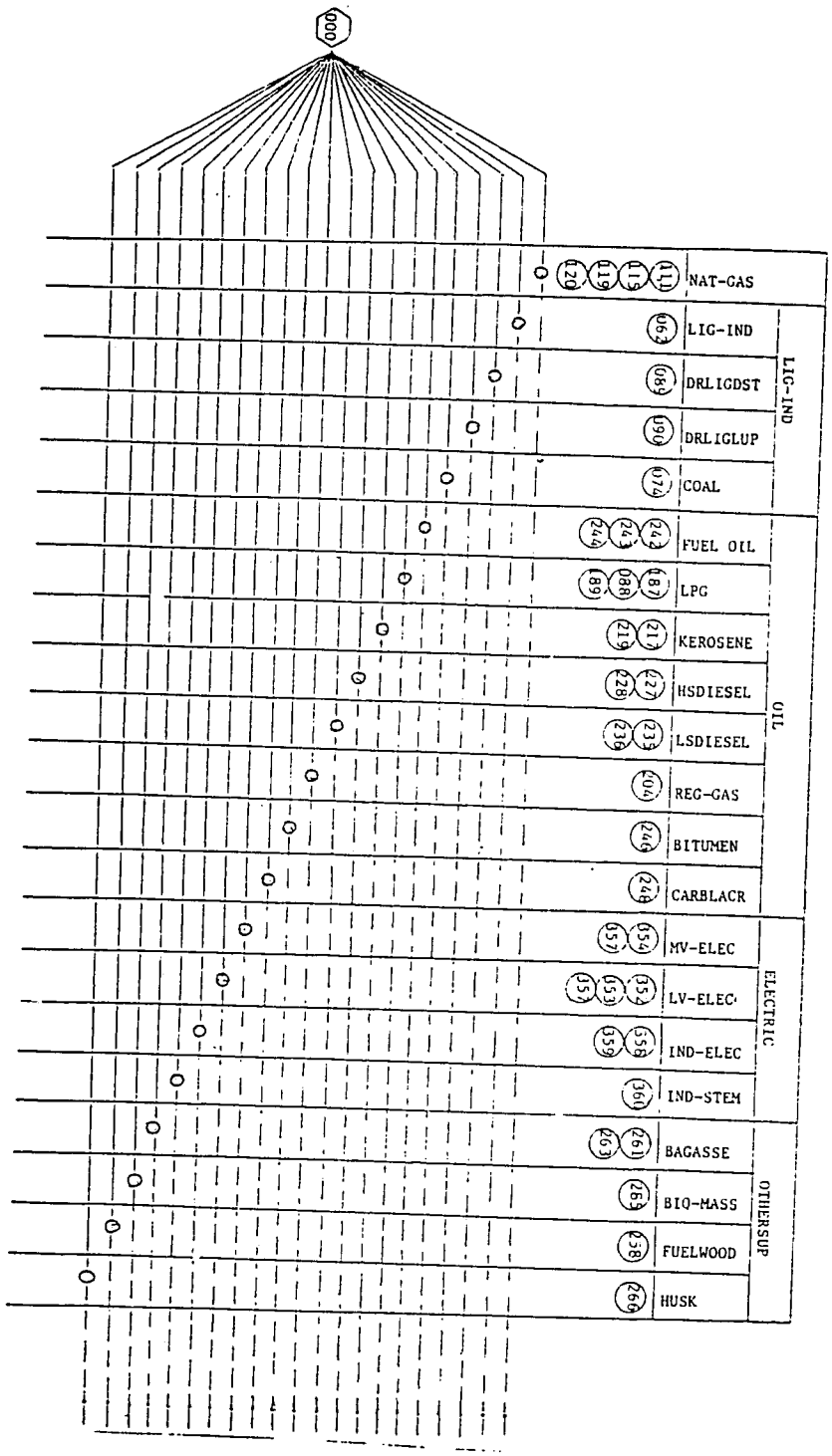


Fig. 3.25 Industry Subsystems



Evaluation of Results

The textile submodel has been installed successfully and can be used as an independent submodel.

Computer runs have been conducted and have been found to be satisfactory.

Issues and Recommendations

Inclusion of Major Activities

As discussed, some major activities in the textile industry are not included or are not considered separately. Accordingly, NEA should review the missing or unseparated activities relating to their significance of energy consumption. These activities should be included in the model.

NEA should conduct a preinvestigation study on the energy used in textile activities and use the findings as a basis for deciding which activities to include in the model.

Development of the Macro Economic Model

The macro economic model should be expanded to cover the activities not included in the EMP to support the model expansion.

Data Bank for the EMP Textile Subsystem

A discussion on the data bank for the EMP textile subsystem is detailed in this subsection to provide a conceptual guideline for future development. A detailed design of the data bank should be made before implementation.

- Data Bank for the Macro Economic Model

Statistics to be kept in the data bank for the macro-economic model should include historical demands for textile activities selected to be included in the model. These include production output and numbers of machines (e.g. numbers of weaving machines).

Other records concerning economic parameters influencing demands of activities should be kept in the data bank. Detailed study is required for the identification of the relevant parameters.

- Data Bank for EMP Textile Submodel

Electricity and steam are mostly used in the textile industry. Accordingly, the consumption per unit output of each activity/process should be kept in the data bank. This will require some effort in conducting surveys and compiling of data/information.

Load characteristics of electricity for textile activities/processes are as discussed in the Electricity subsystem.

Statistics on the textile industry are compiled by the textile related associations such as the Thai Textile Manufacturing Assocation and the Thai Weaving Industry Association. Statistics may be also be available from concerned government agencies such as the Ministry of Industry.

Energy use data may not be compiled by these organizations. Therefore, a sampling survey may have to be conducted for the gathering of the data.

F. THE PAPER INDUSTRY SUBMODEL

Analysis of the Existing EMP Paper Industry Submodel

In the EMP model, the paper industry was broadly classified into 2 categories:

1. Kraft paper and paperboard; and
2. Cultural paper (print, write, hygiene)

The EMP study did not classify the paper industry into detailed categories due to the unavailability of data.

As all paper industry activities are included in the EMP model as aggregates, this limits the capability of conducting detailed studies on the paper industry. The paper industry should be divided in to major categories, such as:

- Kraft paper
- Paperboard
- Print paper
- Write paper
- Hygiene paper

Interrelationship with Other Subsectors

Moreover, bagasse (which is a by-product of the sugar industry subsector) is an important raw material for the paper industry. Bagasse is also used as a fuel for steam generation. Shortage of bagasse, if it is used as fuel, would affect the paper industry. Accordingly, a study on the paper industry should be done in conjunction with the sugar industry.

The Revised Paper Industry Submodel

The paper industry subsystem is considered as a demand subsystem. The simplest way to develop a demand subsystem is to extract the selected

subsystem from the EMP model. Subsequently, the upstream nodes are linked to node "000" and appropriate shadow prices from the EMP optimization run are assigned to these links. See Fig. 3.20.

Data Base for Paper Industry Submodel

As stated in the previous section, the paper industry subsystem itself differs very little from the paper industry subsystem in the overall EMP.

How the data base for the Paper Industry subsystem was designed was discussed previously in Section A of this Chapter. Please refer to "Techniques and Procedures for Developing Data Bases" for an explanation of the overall process of generating EMP submodel data bases.

Evaluation of Results

The Paper Industry subsystem has been installed successfully and can be used as an independent subsystem.

Computer runs have been conducted have been found to be satisfactory.

Issues and Recommendations

Inclusion of Major Processing Activities

As discussed above, major processing activities in the paper industry are not considered separately. Accordingly, the NEA should review the unseparated processing activities relating to their significance of energy consumption. These processing activities should then be included in the model.

NEA should conduct a preinvestigation on the energy used in paper processing activities and use the findings as a basis for deciding which activities should be included in the model.

Linkage with Sugar Industry

Perhaps the paper industry should be linked with the sugar industry subsystem. This will provide an opportunity for studying the use of bagasse as fuel or raw material in the paper industry.

Development of the Macro Economic Model

The macro economic model should be expanded to cover these processing activities not included in the EMP to support model expansion.

Data Bank for the EMP Paper Subsystem

A discussion of the data bank for the EMP paper subsystem is detailed in this subsection to provide a conceptual guideline for future development. A detailed design of the data bank should be made before implementation.

- Data Bank for Macro Economic Model

Statistics to be kept in the data bank for the macro economic model should include historical demands for paper processing activities selected to be included in the model. These include production output and process capacity.

Other records concerning economic parameters influencing demands on activities should be kept in the data bank. Detailed study is required to identify the relavant parameters.

- Data Bank for the EMP Paper Industry Submodel

Electricity and steam are most used in the paper industry. Accordingly, the consumption per unit output of each activity/process should be kept in the data bank. This requires some effort in conducting surveys and compiling of data/information.

Load characteristics of electricity for paper activities/processes are the same as discussed in the Electricity subsystem.

Statistics on the paper industry are limited. Some statistics are available from concerned government agencies such as the Ministry of Industry.

Energy use data may not be compiled by any organization. Therefore, a sampling survey may be needed to gather the data.

G. THE URBAN HOUSEHOLD AND ITS TERTIARY SUBMODEL

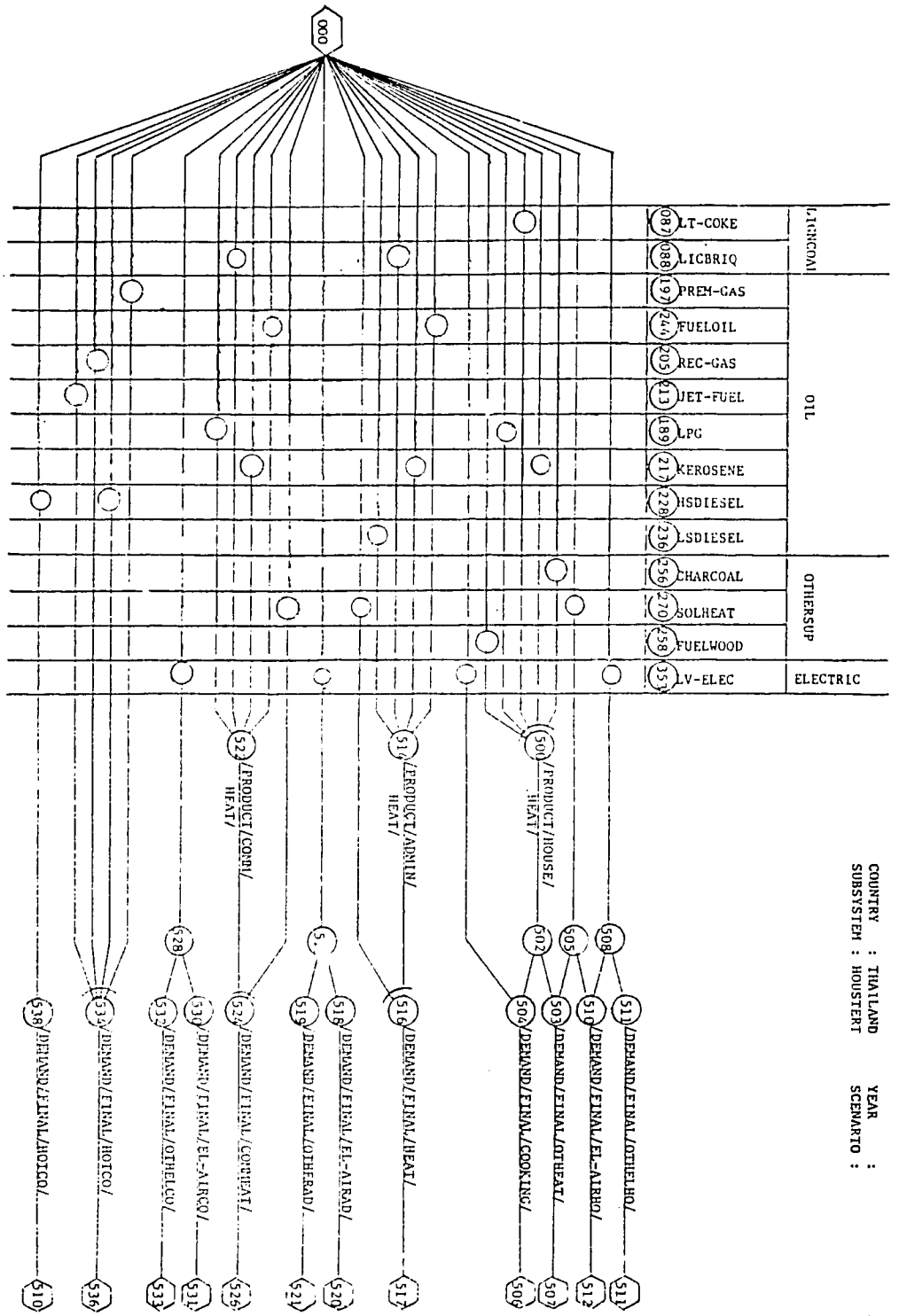
Analysis of the Existing EMP Urban Household and Its tertiary Submodel

The urban household and teritiary (HOUSTERT) subsystem include activities such as commercial heat, urban cooking, administrative air conditioning, commercial air conditioning, residential air conditioning, other administrative heat, other heat, other administrative electricity, other commercial electricity, defense motor fuels, and commercial motor fuels.

The Revised Urban Household and its Textiary Submodel

The Urban Household and Tertiary Subsystem is considered as a demand subsystem. The simplest way to develop a demand subsystem is to extract the selected subsystem from the EMP Model. Subsequently, the upstream nodes are linked to node "000" and appropriate shadow prices from the EMP optimization run are assigned to these links. See Fig. 3.26.

Fig. 3.26 Houstert Flow Diagram



Data Base for the Urban Household and Tertiary Subsystem

As stated in the previous section, the urban household and tertiary subsystem itself differs very little from the urban household and tertiary subsystem in the overall EMP.

How the data base for the Urban Household subsystem was designed was discussed previously in Section A of this Chapter. Please refer to "Techniques and Procedures for Developing Data Bases" for an explanation of the overall process of generating EMP submodel data bases.

Evaluation of Results

The urban household and tertiary subsystem has been designed as an independent subsystem.

Due to time limitations, however, the subsystem has not yet been installed on the computer.

Issues and Recommendations

Since this subsystem has only been designed and not run on the computer no issues and recommendations can be made.

H.CONCLUSIONS REGARDING THE ENERGY MASTER PLAN SUBMODELS

1. Various submodels explained in section "B"-"I" have been built successfully employing techniques and procedures mentioned in Section A.

2. Remote job entry software has been developed to provide NEA with the capability to use its remote Job Entry for the EMP subsystem to be run on the NSO (National Statistical Office) terminal.

3. Its usefulness and potential applications for simulation, optimization of those submodels mentioned previously can be done effectively. Therefore, NEA should utilize those submodel and remote job entry facilities.

I. RECOMMENDATIONS REGARDING THE ENERGY PLAN SUBMODELS

In addition to issues and recommendations mentioned in sections dealing with individual submodels the following are also recommended:

1. The data bank for the various submodels should be constantly updated.

2. Improvement of various submodels should take place whenever data availability permits, with emphasis on the potential expansion of submodels and the establishing of data banks for the remaining subsystem.

3. In-house training for the NEA staff for construction, analysis, interpretation and operation of the models (developed or to be developed), including computer software operation, should be done on a continuous basis.

4. Those who are concerned with energy planning decision-making should become familiar with the submodels (both in technical and lay terms) so that the communication gap between decision-makers and technicians can be reduced.

Chapter 4
Rural Energy Models

Previous Page Blank

RURAL ENERGY MODELS

This chapter discusses the Household Energy Model and the Rural Community Development Model in terms of their general structure, components, results of preliminary model runs, uses and potential modificaions.

A. HOUSEHOLD ENERGY MODEL (HEM)

General Structure

The Household Energy Model (HEM) is designed to simulate the decision-making process of a village household when choosing among different sources of energy, allocating the energy to different activities, and selecting the conversion and end-use technologies for these activities. The demands of the household are determined by the size of the household, the amount of the land and the quantity of animals owned.

The model is divided into six components: agricultural, animal husbandry, crop-processing, household, sources of energy and the conversion of energy, and income for activities and costs of the resources.

The model determines what activities the household will undertake and what resources it will use from a limited supply. The allocation of the resources is based on maximizing net income subject to the constraints relating to minimum requirements.

The model is structured in the form of a linear program. It takes the characteristics of the agricultural and animal husbandry models and incorporates them into an analysis of energy flows.

Four types of relationships are specified in the model: resource constraints, production functions, output constraints, and the objective function.

The linear programming (LP) model serves as an accounting tool which keeps a record of the use of all reources and the outputs of all the activities, and allocates resources.

The advantage of using an LP model is that the effect of reallocating one resource or changing one level of activity is examined in terms of its effects on all other activities and resources in the system. The change in

one parameter creates impacts which ripple through the system of household activities.

The model is designed differently from the EMP model in that it does not attempt to answer all questions regarding the flow of energy in the village. Rather, it examines the decisions that a household will make when confronted with a specific supply of resources and range of activities and technologies.

The analyst should use the model in a dialogue mode. A series of model runs should be made to determine what the effects of a change will be on the different socio-economic groups. A change in resources, technologies or activities, the effects of changes in single parameters, the effects as the prices rise, as yields improve, as conversion efficiencies increase, as the supply of land decreases, fuelwood diminishes, or irrigation water is reduced, etc. should be examined.

The model is designed to reflect decisions made by the household; the resources available are similar to those available to the household. These resources can be divided into three groups:

1. Controlled directly by the household;
2. Owned by the village; and
3. Supplied by the market outside of the village.

The outputs from the different household activities can also be divided into three groups:

1. End-products consumed directly by the household;
2. Intermediate outputs used as inputs to other household activities; and
3. Goods sold either in the village market or to traders from outside of the village.

The model is bounded by the definition of the household. It permits interactions between the household and other households in the village (in the form of an exchange of resources and products) and between the household and the region outside of the village. The movement of resources across the household boundary is generally in the form of shared resources which are limited in supply and may or may not have a cost. The movement of products or intermediate outputs across the household boundary into the village or regional markets is not included.

The model has the capability to examine a range of options for resource use and conversion: types of land, types of crop packages, types of animals, number of time periods, and types of energy conversion equipment. The model is designed to accept up to four different types of land: household-owned lowland, household-owned upland, village pastureland, and forest land.

The crop package includes type of crop, season in which it is grown, the type of land, the input requirements for labor, traction power, fertilizer, irrigation, and the yields of crops and field residues. The model includes 14 crop packages; plain rice for upland and lowland in the

rainy and dry seasons, cassava for upland and lowland in the rainy season, vegetables for upland and lowland in the dry season, sugarcane as an upland perrenial, grass as a perrenial crop on upland or village, and eucalyptus as a perrenial on upland or village land, and dipterocarp trees on forest land. The maximum number of crop packages can be 99.

The types of animals include draft animals and animals grown for slaughter or sale. The number of animal types is limited to nine. The animals included in the model are bullocks (water buffaloes), cows, and pigs. Animals are defined in terms of their feed labor requirements, annual production capacity for traction, and forms of work.

The model allows the resource flows to be determined for up to six time periods to more accurately account for resources which are only available or required during certain periods of the year and more precisely define activities which occur at certain times.

The number of energy conversion devices is unlimited, but must be defined separately and added to the structure of the model. The definition for "device" includes the capital costs, the operating cost, the labor inputs, and the efficiencies conversion from one source of energy to another. The model includes: a hand tractor, a biogas digester, a biogas-fueled gas engine, a diesel engine, a gasifier-equipped diesel engine, an electric motor, an electric generator, a sterling engine, a steam engine, a windmill, a hydro-electric generator, a transmission device for using draft animals, various types of charcoal kilns, and charcoal and wood cooking stoves. Crop processing equipment is included in the model but only the input requirements and conversion ratios are included in its description.

The fuel and energy sources are: collected fuels (e.g. fuelwood, field residue, crop processing residue and dung), processed energy (e.g. charcoal, producer gas, and auto-generation electricity), and commercial fuels (e.g. petroleum-based fuels, grid electricity and purchased charcoal and fuelwood).

The definition of "household" includes: the size of the family, the amount of land controlled, the quantity of animals controlled, ownership of a tractor, access to grid electricity, and preference for charcoal or wood cooking.

The Components and Coefficients of the Model

The structure of the model includes activities--agriculture, animal husbandry, crop processing, domestic activities, and an energy conversion--defined as separate components. They are interrelated by the exchange of inputs and outputs. Each component contains equations defining: the inputs required for direct consumption, the inputs to production activities, the conversion factors and production functions, and the outputs produced. The detailed presentation is available for those who wish to pursue the model structure and equations in greater detail in Volume 3 of the Meta Systems report.

Agricultural Component

The agricultural component contains land use crop production, irrigation, traction power, fertilization, and farm labor. Land was allocated to the different crops according to season, land type, and the economic returns. The model allocates the land to crop packages which offer the greatest net income.

The productivity of each crop package is primary crop yield and field or harvest residues. Irrigation water requirements are specified for each crop package. The model computes the total irrigation requirements by season and the amount of pumping energy required.

The traction power required for preparing the land can be provided by draft animals, tractors or human labor. The amount of time required by each energy source is included.

The labor requirements for cultivation are in person-hours required per unit of land planted in each time period.

The fertilizer requirements are in nutrient requirements: nitrogen, phosphorous, potassium and organic matter. The sources of fertilizer include chemical fertilizer, manure, crop residues, and crop processing residues.

The crops are consumed directly, sent for processing, or sold as income. Crops consumed are assigned to the household while those processed are assigned to crop processing.

The field residues can be used as fertilizer to meet the nutrient requirements, fed to the animals, burned as a fuel. The residue lost due to deterioration while lying in the field or in storage is accounted for by a maximum utilization coefficient.

Pastureland and wooded areas are entered as crop packages and are treated as perennials. They can be cultivated or uncultivated crops. The output can be specified to occur in a single time period or during all time periods. The effect is the same since they can be used throughout the year as a fodder and fuel, respectively.

The yields for different crop packages were determined from the results of the project survey (REP survey), and the data from the publication "Agricultural Statistics of Thailand, Crop Year 1980/81" in terms of the weight of the crop prior to processing. For perennial crops yield is stated in terms of the average sustainable yield. Since these parameters vary by region and year as well as variety of seed, they should be re-estimated using local survey data or agricultural census data. The yields for pasturelands and woodlands were estimated from non-Thai sources.

The quantity of residues left in the field depends on the type of crop and the method of harvesting. The quantity of field residues was measured directly for several types of crops as part of the REP survey. A ratio of crop weight to field residue weight was determined. The survey data were supplemented with data provided in the report "Agricultural Residue

Utilization" (by Veera Piriyaparn of the Thailand Department of Agricultural Extension) and were compared with data from other countries. The quantity of residues was measured as oven-dried weight. The variation in these coefficients is more extreme than for the crop yields because of differences in harvesting techniques. These residues are important sources of fuel, fertilizer and feed. More careful surveys should be performed.

The requirements for irrigation water were computed only for vegetables and rice planted in the dry season (based on the data in the FAO report, "Yield Response To Water" by Dorenbos and Kassam) and were adjusted to account for the three month growing season. The average rainfall during this period was estimated from rainfall data recorded over a ten year period in Bangkok. The amount of irrigation water was computed assuming a loss in the canals and storage ponds of 33 percent.

The amount of energy required to pump the irrigation water was computed, assuming that the water had to be raised 4 1/2 meters and that the efficiency of the pump was 80 percent, resulting energy required per cubic meter of water pumped is .02 horsepower-hours. A sensitivity test in the range of .01-.06 horsepower-hours should describe most situations.

The required inputs of human labor, animal labor, or tractor-power for land preparation (esimated from data collected as part of the NEA rural energy survey and data published in the "Agricultural Statistics Report no.47 of the Office of Agricultural Economics) was made based on the number of ploughings required (which were determined to be three for transplanted rice and vegetables and 2 for all other crops). The resulting requirements are summarized for a two wheel tractor, a bullock, a cow, and a person working unassisted. This data should be collected through surveys conducted during or just at the end of the ploughing period.

The fertilizer requirements for different crops were assumed to be supplied through a mix of manure, field residues and chemical fertilizers--measured in terms of four nutrients: nitrogen, phosphates, potassium, and organic matter. The requirements were determined from FAO data which was adjusted to reflect the situation in Thailand. Thailand-specific data was available in three sources: the national agricultural statistics (in ratio of nutrients consumed in chemical fertilizers), the EMP survey (in disaggregated ratio for individual crops) and, the REP survey (in application rates by crop type disaggregated for farmers using chemical fertilizers). The inputs to the model and the results can be simplified by limiting the data to a single nutrient such as nitrogen.

The supply of nutrients from field residues were determined based on the Thailand Department of Livestock, from the FAO, and from a report by Van Buren. This data was generally limited with the most information available on phosphorous content and the least data available on potassium content. Additional efforts should be made to improve the accuracy of these parameters.

Chemical fertilizers were estimated assuming a standard mixture of 14:14:5. The supply of nutrients per kilogram of dry manure was assumed to be constant and was based on published data summarized in the "Technology Monitoring Report."

Animal Husbandry Component

The animal husbandry component describes the care and feeding of the animals and the output, including draft labor, animal products and manure.

The feed requirements of the animals are crude protein, metabolizable energy and dry matter. The first two represent requirements that the animal must receive to maintain its ability to work and produce products. The third requirement is the maximum quantity of dry matter that the animal can consume to prevent feeding the animal with poor quality fodder. The crude protein requirements, specified in terms of digestible crude protein, depend on the type of fodder for ruminant or non-ruminant animals.

The feeds available include field residues and crop processing residues. The nutrient values are included in the parameters discribing residues. The model allocates the residues to the animals based on the nutrient requirements and demands for fertilizers or fuels.

The demand for draft animals for ploughing, determined in the agricultural component, must not be greater than the number of hours that the animals can work. Surplus hours are available for non-ploughing purposes: e.g. crop procesing, water pumping, etc. The power output of each type of animal on a sustainable basis is multiplied by the conversion efficiency factor assumed to apply when using animals for activities other than land preparation. Net power output is multiplied by the number of surplus hours to determine the energy available to the energy conversion component.

The production of the animal products is calculated on an annualized basis. This is input to household to meet the food requirements. The excess is sold for income.

The dung average (daily output in dry-matter) from each type of animal is used to compute the amount of dung produced during each period. The dung can be used as a fertilizer, but the quantity is reduced by a utilization factor which accounts for the deterioration prior to collection and the difficulty in collection from grazing animals. The dung is input to the agriculture component as manure and can also be used as a feedstock for a biogas digester as input to the energy conversion component. The slurry output from the digester has nutrient values and is available as an input to the agriculture component. Labor is required for collection from pens and fields and distribution in the fields. There is additional labor of curring the dung to the digester, loading it into the digester, and unloading the slurry.

Water for the animals is assumed to come from a public source without pumping and with very little demand for labor. The demand for water is computed from the average daily requirement per animal, multiplied by the length of each time period.

The amount of labor required for animal husbandry was computed from the amount of labor required for supervising animals during ploughing and

was assumed to be proportional to the number of animals owned by the household. Cows and buffaloes were each assumed to require 1 1/2 person-hours per day during the seasons when they were left to graze and 1 person-hour per day during the seasons in which they were kept either penned or tethered. For pigs, an estimate of 2 person-hours per day was assumed. Further analysis should be made with regard to this labor requirement. The human labor required for supervising the animals during ploughing was based on the number of animals used. It was assumed that the buffaloes were worked individually, but that the cows were worked in pairs.

The animal feed requirements were calculated in terms of three digestable nutrients--crude protein, metabolizable energy and dry matter. The nutrient requirements per animal were computed based on the average liveweight of the animal: 500 kilograms for a buffalo, 250 kilograms for a cow and 100 kilograms for a pig. The values were obtained from "The Water Buffalo: New Prospects for an Under-utilized Animal" and the Thailand Department of Livestock publication by Pipiyaparn "Feeds and Feeding". The two types of crude protein specified are digestible crude protein for ruminants and crude protein for non-ruminants.

The nutrient content for various types of feed was determined by the Thailand Department of Livestock. The parameter is used to relate the type of feed to the type of animal: digestible crude protein consumed by ruminants and crude protein for non-ruminants. The data on nutrient content is reasonably accurate but the data on nutrient requirements should be reviewed.

The uses of residues for animal feed and fertilizer are computed on an annual basis. The seasonality of the supply of residues has not been encluded explicitly in the model. A factor was introduced to account for the maximum fraction of the supply of field residue that could be used for feed and fuel. The values are preliminary estimates and should be adjusted.

The outputs from animals are energy (traction power for agriculture and other power) and products (meat and milk). Traction power for agriculture was in hours required to plough a rai of land. Other power was the power output which could be delivered by an animal over a sustained period of time for a variety of activities such as waterlifting, crop processing, and transport. For buffaloes and cows the maximum sustainable power output was estimated from data in the FAO report Energy for Work Agriculture to be .78 hp and .4 hp, respectively.

The annual meat production was computed, by multiplying liveweight by the percentage of edible meat and divided by the expected life of the animal, to be 50 percent for buffaloes and cows and 60 percent for pigs. The expected life was assumed to be ten years for buffaloes, seven years for cows, five years for lactating cows and one year for pigs. The estimates of energy and product output are largely from non-Thai sources. Since the primary use of the buffaloes and cows is for traction power for agriculture, the accuracy of the coefficients describing other outputs is not important.

The quantity of dung produced by animals was part of the REP survey. The oven-dried dung production measurements were used to estimate the seasonal outputs.

The Crop Processing Component

The crop processing component describes the conversion of crops to products and residues and the labor and energy requirements for this processing. The model determines the technology which yields the highest net income. The net income is determined by the conversion factors of the technology and the requirements for labor and shaft power. It does not take into account the differences in fixed capital costs of these technologies.

The processed products and residues are food, fertilizer, fodder, and fuel. The products and some of the residues can be sold.

The quantities of crop processing products are computed by multiplying the amount of crop processed by technology-specific conversion factors, the weight of air-dried products and residues produced per kilogram of air-dried crop input. The conversion factors were determined from the REP survey, the NEA survey of small industries, P.Gimmer's report in Indonesia, and an FAO report on tropical feeds.

The crop processing technologies considered for rice milling were the small scale rubber-roller mill, the grindstone mill generally powered by an electric motor, and the large-scale steam-powered grindstone mill. Cassava processing is associated with different products; the portable chipper with small engine, the pelletizing mill which is belt driven and generally includes a portable chipper, and the large-scale cassava flour mill. For sugarcane, the technologies selected were the small-scale grinder and the commercial-scale facility. The accuracy of the parameters could be increased through an additional survey with careful weighting of inputs and outputs, if the crop processing component is a major consumer of energy.

The energy requirements, collected in the REP and NEA surveys of rural industries, are in terms of the energy requirement to process a kilogram of crop.

The labor requirements were estimated from the REP survey. Better data could be obtained if the model's allocation of labor proves sensitive to this parameter.

The Household Component

The household component describes demands for food, cooking, lighting and water as well as for the supply of labor. The members of the household are adults and children (under 12 years of age). The total household is quantified in terms of adult-equivalents (to determine the quantity of food, water and cooking required), workers, and members (to determine the quantity of domestic labor required for maintaining the household).

Household cooking uses wood, charcoal or biogas. The demand for cooking fuel is determined based on the average daily requirements per adult-equivalent for each time period, by inputs of cooking heat from the energy conversion component. The lighting requirement is an annual demand met either by kerosene or electric lighting with a fixed quantity of energy required.

Food consumption is met by crops from the agriculture, processed crops, and animal products. The model allocates a sufficient quantity of each to meet the household requirements before crops go to alternative uses or to the market for sale.

Water consumption is calculated in a manner similar to food consumption and there are no limits to the supply of water. It is assumed that there is a sufficient supply of water for all uses. The water supplied to the household is from wells located near the household without pumping and only a small requirement for labor to collect water.

The household laborers are available on a seasonal basis to the various activities. Additional labor is hired if its costs are less than its marginal product, and is sold when there is an excess.

The seasonal labor demands include operation of tractors, controlling animals during ploughing, hand ploughing, cultivation of crops, domestic chores, care of animals, crop processing, fuelwood collection, water collection, charcoal-making, biogas digester operation, and motor and engine operation. The non-seasonal labor demands include collection and distribution of manure, field residues and process residues for use as a fertilizer, and the collection of field and process residues for use as a fuel.

Energy requirements for cooking, computed in terms of the kilocalories required per adult-equivalent per day, were selectd to reflect conditions in Korat. The conversion efficiencies for the stoves using both wood and charcoal were determined from extensive physical tests made as part of the REP survey. For biogas fueled stoves, the efficiency had to be estimated since these units are not widely used. In regions where there is widespread use of biogas stoves or there are regional stove designs, further analysis of the appropriate values for the conversion parameters may be required.

Lighting includes kerosene lighting and electric lighting. The data from the REP survey, which is in general agreement with that from the EMP survey, was used for estimating demand. The average values for kerosene used in non-electrified households and electricity consumption in electrified households were taken from the complete survey sample. Electricity consumption includes the consumption of electricity for home appliances.

The amount of food consumed for rice was estimated using data from the REP survey for the Korat area. Meat and vegetable consumption were estimated from survey data collected on the frequency with which these types of foods are eaten. It is assumed that the per capita consumption on the days in which these foods were eaten is 1/4 lb for meat and 1/2 lb for vegetables.

Labor available within the household was estimated by counting the adults (age greater than 11) and assuming that they could work a ten-hour day, seven days a week for sustained periods of time.

The daily demand for household labor was assumed to include three person-hours spent cooking each day, a person-hour spent in kitchen-related work, and an additional person-hour required per household member.

The domestic labor demand does not include the time required for collection of fuelwood which is separately specified. The demands for domestic labor were estimated and accuracy of these parameters should be reviewed, especially where they represent a serious constraint on the demands for labor.

The demand for water by season (15 liters per capita per day) does not include water for bathing or clothes washing since these activities generally take place at the source of water rather than in the household. The time for fuel collection varies by region and by village so that these parameters should be adjusted according to data collected in that region.

The labor required to collect water (.005 to.03 person-hours per liter) has been included. The labor required to provide water for animals is much lower, since in most cases the animals will travel to the source of water, and has been included in animal husbandry.

An estimate was made for the labor required to collect dung for use in a biogas digester and to remove the slurry from the digester. The time to remove the slurry does not include the time for distributing this slurry in the fields.

Energy Conversion Component

The energy conversion component describes the equilibrium between the demands for and the supply of shaft power, the production and uses of autogenerated electricity, the consumption of biomass fuels, the production and uses of charcoal, and the consumption of fuelwood.

The model allocates the shaft power from a variety of sources to a variety of activities. For each source, the cost, rate of fuel consumption and labor requirements are specified as well as the number of hours of operation during each time period. The shaft power requirements are determined for each activity. The capacity of each source is determined by dividing the energy required during each time period by the the hours of operation in that time period. The maximum capacity requirement is increased to meet peak demands. The final value for capacity is multiplied by the annual capital cost per unit power to obtain the fixed cost for each source. The total cost is the sum of the fixed cost and the costs for fuel and labor. For sources of power, influenced by seasonal fluctuations, the calculation of the capacity includes a utilization factor during each time period.

The labor required for the sources of shaft power is obtained from the household or through hired labor. The model calculates the labor requirements for each source as a linear function of the amount of energy produced.

The sources of electricity available to the household (used for household lighting and for electric motors) are grid, hydro-electric or self-generated. Excess capacity can be sold.

The consumption of petroleum, biomass, fuelwood and charcoal are computed. There is no limit for the supply of petroleum. Biomass fuels, obtained from residues or from dung, can be consumed in a biogas engine and biogas cooking unit. The residues, obtained as field residues and as process residues, can be used as fuels for the external combusion engines and as feedstocks for charcoal-making.

Charcoal can be purchased or produced. Technologies for wood kilns are included. Charcoal is used in dual-fuel, gasifier-equipped engines, in charcoal stoves, and can be sold. Fuelwood is used directly, converted to charcoal, or replaced by biogas.

The use of tractors and animals, other than providing traction power for agriculture, has been included by estimating the average sustainable output when these sources are used to provide stationary shaft power. For the tractor, a two-wheel, hand-tractor with a 9 hp, diesel-fueled engine was assumed. The sustainable output alternative application is assumed to be 4 horsepower. The maximum number of hours of operation on a sustainable basis is assumed to be 10 hours per day, or 300 hours per month. It was assumed that the tractor would be operated about 2,000 hours per year.

The other types of stationary shaft power included in the model are electric motors, petroleum-fueled engines, biogas-fueled gas engines, windmills, gasified-equipped dual-fuel engines, sterling engines and steam-driven, reciprocating engines. The rate of fuel consumption for all of these devices, with the exception of windmills, was computed in terms of fuel quantity per delivered horsepower hour based on the standard efficiencies of these devices.

The labor required for operating stationary engines, except those fueled with biomass, is proportional to the number of hours that the engine is operated. The labor requirement per horsepower-hour was made by assuming horsepower.

The horsepower capacity required to provide stationary shaft-power demands was computed by comparing the seasonal demand in horsepower-hours with the maximum number of hours of engine operation during the season and assuming that all engines could be operated 10 hours a day-except boiler-equipped steam engines (which could operate 12 hours per day) and gasifier-equipped diesel engines and sterling engines (which could operate 8 hours per day). The spare capacity to handle peak load was assumed to be 2/3 of the average load.

Electricity is provided by rural electrification from the grid, autogeneration by a motor or engine (assumed to have a conversion efficiency of 0.9 with labor required limited to operating the engine) and hydro-electric power. The parameters which specify the availability of electricity from hydro-electric power are: the average load factor, the number of hours of operation per season, and availability of water for producing the electricity in each season.

A windmill is assumed to have a rated capacity equal to 500 percent of the average output during peak season. The amount of energy available is determined by a seasonal utilization factor, computed based on the percentage of time the wind speed is in excess of 10 mph. Since the windmill provides intermittent shaft power, available energy is equal to the number of hours of use in the season multiplied by 1/5 the rated capacity of the windmill.

The rate of fuel consumption in a biogas digester is 4.0 kilograms of oven-dried dung per cubic meter of biogas. The amount of labor required is for loading the manure into the digester and removing the slurry from the digester.

The inputs to the charcoal-making process include feedstocks and labor. The rate of conversion from feedstock to charcoal is specified for wood-fueled kilns and for residue-fueled kilns. The technologies are the rice-husk pit kiln, the mud-covered pit kiln and the permanent mud-dome kiln for wood, and the barrel kiln for residues. The conversion factors are defined in terms of oven-dried kilograms of wood to oven-dried kilograms of charcoal for the three wood kilns. For the residue kiln, the rates of conversion are assumed to be 6 kilograms of oven-dried field residue or 7 kilograms of air-dried process residues per kilogram of charcoal.

The labor required for charcoal-making (including loading the feedstock and unloading the charcoal, supervising the operation of the kiln, and repairing the kiln between firings) was estimated from data in the REP survey. From this data and estimated kiln sizes, the required person-hours were extrapolated. The typical kilns were a rice-husk kiln with an input capacity of 220 kilograms, a mud-dome kiln with an input capacity of 600 kilograms and a barrel kiln with an input capacity of 100 kilograms of residue.

Costs

The model operates on the principal of maximizing the net income of all household activities based on the costs for all resources and the income from all outputs. The values of agricultural outputs were determined by comparing wholesale prices in Bangkok in mid-1982, less 20-25 percent for the middleman's fee, with data on farmgate prices from the REP survey and data on wholesale prices in Khon Kaen at the end of 1981.

The cost of hired labor was estimated to be 3.75 baht per hour and household labor was set at 2 baht per hour.

The costs of fuels and electricity were set equal to current prices, based on existing PEA rate and data collected in the REP survey.

The cost of land was the price of land in Korat, converted to an annual cost using a discount factor of 6 percent based on a rate of interest of 12 percent, reduced by 6 percent to allow for risk aversion.

The costs for capital items including animals, equipment and fuel conversion devices were determined by annualizing the purchase price of the item over its useful life. The capital recovery factor computed assumed

that there was no scrap value and that the discount factor was 17 percent per year. This percentage was computed by taking the real interest rate of 2 percent per month and reducing it by the rate of inflation which averaged 12 percent per year over the period 1978 to 1982.

The value of animals, determined in the REP survey, was amortized over the useful life of the animal. The price of the animal reflects current wholesale prices for meat and milk. The purchase price for the different equipment and fuel conversion devices was based on the information reference presented in the "Technology Monitoring Report," computed in baht per unit capacity, and was added to an annual cost for repair and maintenance. These figures are preliminary estimates and should be revised.

Results of Preliminary Model Runs

A series of model runs were conducted to determine the robustness of the model and to perform a sensitivity analysis on the results.

The Base Case

A base case was chosen using prototypical data from Korat. The household contained 4 adults and 2 children, controlled 20 rai of farmland (12 lowland rai and 8 upland rai), able to use 15 rai of public grazing land and 5 rai of forest land, had one buffalo, 2 cows, a pig and a tractor, had access to grid electricity and irrigation water. The crop packages included rice and cassava in the rainy season, vegetables and irrigated rice in the dry season, and sugar and eucalyptus trees throughout the year.

In the rainy season, the major crop planted was cassava. Just enough rice was planted to meet household requirements. The household grew rice as an irrigated crop in the dry season. Vegetables were the major cash crop grown in the dry season. A limited area was planted in sugarcane to provide both a cash crop and some animal feed for the pigs, since the only other source of pig feed was rice bran which could be sold for 3 baht/kilogram. The separation of potential feed sources between ruminants and non-ruminants created some significant constraints since the model does not allow for purchased feed.

The agricultural production during the dry season required over 18 thousand cubic meters of irrigation water to be pumped by electric motor since the cost is below that of the various types. The bullock and the tractor were the primary source of traction power for land preparation. The bullock was used up to its limit in both seasons and the tractor was assigned only fractionally to meet the traction requirements for the first period's land preparation. The cows were used only to provide the additional level of demand for traction power in the dry season. The bullock was sufficiently utilized for draft work and the pig for producing meat, but the cows were underutilized and had a negative economic value.

The cooking was done using fuelwood from the forest, supplemented with purchased fuelwood. Hired labor had to be employed in four of the six time periods. The price for selling labor was too small (1/2 baht per hour) to attract household labor even in the slack periods.

Chemical fertilizers supplemented the nutrients, manure and field residues. Process residues were not used except for bagasse as a fuel in the production of sugar. The processing residues of rice were sold, the cassava was pelletized so no residues were produced and the vegetables were not processed. All dung was used as a fertilizer, not in a biogas digester because of the cost.

Changes in the Availability of Energy Conversion Technologies - A Sensitivity Analysis

- When grid electricity was removed by increasing its price, the household switched over to petroleum-fueled engines and a full tractor. Income dropped by about 8 percent. The cropping patterns remained basically unchanged, except for an increase in the quantity of sugar planted. The cows were no longer used for draft power. The tractor was used for processing of the rainy season crops. This result was somewhat unrealistic since the processing activity is primarily pelletizing of cassava. The use of hired labor increased, especially in the rainy season, for land preparation for sugarcane. The cooking activity and the collection of wood was unchanged. The household lighting changed to kerosene.

- The use of petroleum-fueled engines was eliminated in addition to grid electricity in the next model run by increasing their prices. The household switched to dual-fuel, gasifier-equipped engines for shaft power. The net income dropped by 1 1/2 percent while consumption of petroleum fuel dropped by 30 percent. The tractors and lighting continued to consume significant quantities of petroleum fuels. The petroleum fuel is replaced by purchased charcoal due to a lower economic cost than home-made charcoal. In none of the sensitively runs did the household make charcoal because the purchase price used in the model is too low and the labor requirements are too high.

- When the dual-fuel gasifier engine was eliminated by increasing its capital cost, the household switched over to sterling engines for shaft power. The tractor continued to be a source of shaft power for crop processing of rainy season crops, but the sterling engine was used to provide irrigation pumping in the dry season and some crop processing in both seasons. The income changed only slightly. More hired labor was required to operate the sterling engine, fueled with rice hulls and bagasse. No wood or charcoal was used as a fuel and no other residues were used as combustible fuels. The limited fuel supply caused a shortage of horsepower in the processing of rainy season crops. Part of the cassava was milled because of an incorrect parameter which indicated that the milling process had an energy requirement less than that for pelletizing.

- When the sterling engine option was eliminated, the household switched to using the tractor for all stationary shaft power applications and caused a greater shift of cassava from pelletizing to milling. When the price of petroleum fuels was increased dramatically, the household stopped using the tractor and switched over to animals for traction and steam engines for stationary shaft power and an

electric generator to provide household lighting. This resulted in an increase in the use of hired labor and in a 10 percent drop in household income.

- When the steam engine was eliminated, the household switched to the more costly biogas-digester and gas-engine combination with a resulting drop in income of 3 percent. The household used the biogas to provide shaft power, to generate electricity for lighting, and for cooking. The amount of public forest area used was reduced by about one-half. Fuelwood continued to be used for about half the cooking because the amount of labor required to collect the wood is slightly less than to collect the dung and operate the digester. More labor was hired.

The windmills and hydro electricity-powered motors were not connected into the household.

Changes in cooking fuels-A Sensitivity Analysis

- When the household was prohibited from using wood cooking it chose purchased charcoal cooking (rather than a biogas digester or homemade charcoal) since the cost was less. The net income was reduced by only 1 percent. The household no longer used the forest area to supply wood. When the price of purchased charcoal increased significantly, the household made its own charcoal using a permanent mud-dome kiln. The net income was still only about 1 percent lower than the base case. Since the forest area was not sufficient, the household purchased about 45 percent of the total quantity of charcoal used.

- When the household was restricted to biogas cooking, the net income dropped by 2 1/2 percent due to the cost of the biogas digester. Since the digester was limited to the size required for cooking, no other uses were made of biogas despite the availability of a considerable surplus of dung. The change in use of hired labor, agriculture, and animal husbandry were insignificant. The forested area was not used by the household.

Changes in Household Assets - Scenario Runs

- The Wealthy Household

The model was run with a wealthy household with four adults, two children, 24 lowland rai, 16 upland rai, 2 bullocks, two cows, five pigs, and one tractor as well as access to grid electricity, 20 rai of pastureland, 5 rai of forest, and irrigation water. This household had a net income about 75 percent greater than the base-case household. The area planted in rice and sugarcane was similar to that in the base case. All the additional land was planted in cassava during the rainy season and in vegetables during the dry season. The use of the tractor and the buffaloes was doubled, and although the cows continued to be underutilized, their hours worked nearly tripled. The use of chemical fertilizers and electricity both doubled due to increased planting and due to increased crop processing and irrigation. The need for hired labor increased dramatically. The bran from milling the rice was fed

to the pigs rather than sold. A larger percentage of the field residues were for fertilizer.

- The Poor Household

The household resources were reduced so that they included only 6 lowland rai, 4 upland rai, and 1 buffalo, with access to grid electricity, 10 rai of pastureland and 5 rai of forest. The household continued to grow cassava in the rainy season and vegetables in the dry season but its net income was 45 percent lower than in the base case. The growing of rice was still limited to subsistence level production. The sugarcane was no longer planted because there were no pigs nor hired labor. In order to utilize the surplus household labor, the pastureland was planted with eucalyptus which was made into charcoal and sold. The household continued to cook with wood obtained primarily from the forest. The shortfall in this supply was made up with wood from the eucalyptus woodlot.

Conclusions Regarding the Households

The base-case, rich, and poor households have significantly different levels of activity. Since the number of household members was held constant, the household with limited resources had a surplus of labor while the household with considerable resources had a serious deficit.

Conclusions Regarding the Model

The model appears to perform in a reasonable manner. It accepted a wide variety of changes in inputs and provided logical answers. It also showed considerable sensitivity to parameters. The interaction between the energy conversion component and the agricultural and animal husbandry sectors was not as dramatic because residues were rarely used as a fuel. The primary competition for residues was between fertilizer and fodder uses.

The major limitation which was observed is that the model's income maximization objective excludes certain activities (such as charcoal cooking, biogas generation, steam engines, rice as a cash crop, autogeneration of electricity, charcoal made from residues, and pit kilns using rice hulls or earth) given the existing data.

It is necessary to examine the input parameters for accuracy while reviewing the benefits from some of these options which might not appear in the objective function.

Uses and Potential Modifications of the Model

The model can be a very powerful analytical tool when applied to the types of problems for which it was designed. The specific applications for this model should be developed as the NEA analysts become familiar with its operation, its data requirements and the interpretation of its outputs.

Uses of Model

The following is a general summary for the uses of the model.The model:

- Can measure the demand for unpriced resources which serve as complements or substitutes for commercially available resources;

- Cannot determine the demand for different commercial products as a function of price or of income; this type of analysis is best left to economists working with consumer expenditure surveys;

- Can determine the implicit cost of a technique or technology to the rural household.

- Can determine the shadow prices for various resources used in the rural area;

- Cannot project the rate of acceptance of a new technique or technology. Where there are competing techniques and technologies it will always chose the one which has the lowest cost or produces the highest net income. This choice will not change unless the underlying cost factors are also changed;

- Can determine the opportunity cost, i.e., reduction in net income, which would result if the household used a technology or technique other than that chosen by the model;

- Cannot make value judgments or predict consumer behavior on a basis other than the maximizing of net income. Such issues involve analysis of consumer preference and the use of utility theory;

- Can make use of forecasts of consumer behavior to determine the implication on the demand for resources in the rural area;

- Cannot project the rate of acceptance of new programs or policies introduced from outside the village; and

- Can indicate the cost to the household of these programs or policies and the effect on the household's use of resources and level of economic activity if it adopts these programs or policies.

The model's usefulness depends directly on the skill of the person using this tool. The model is to be used in a dialogue mode, with the analyst asking "what if?" questions.

Potential Modifications of Model

This model general structure has been designed to be modified as required for the question being asked and the region being analyzed.

- Non-Structural Changes

The parameters which can be modified are the household

parameters, the regional parameters, the technical parameters, and the price or cost parameters.

- The household parameters which are used to model the different socio-economic groups in a village decribe the household's access to resources. Modifying these parameters will indicate the effects of resource availability on the decisions of the household regarding energy use and level of economic activity;

- The regional parameters which describe the types of crops grown, the time periods of agricultural activity, the use of animals and the types of land available for agricultural and other biomass production. It is important that the inputs be limited to those which are appropriate to the region being studied.

- The technical parameters include the values for physical conversion efficiencies, chemical conversion factors, and energy supply and conversion characteristics, generally based on engineering or scientific analysis as reported in publications.

- The price or cost parameters affect the movement of resources across the household boundary into the village and regional markets, not only between regions but also within regions.

In its present form the model has three types of animals, fourteen crop packages, four land types, and six seasons. For each animal type or crop package added to the model, the matrix increases by about 17 rows and 20 columns. The size of the model's matrix is proportional to the number of seasons raised to the second power. It is difficult to adjust the time periods since they affect almost the entire set of parameters. Such a change could be made by adjusting the length of each time period or by changing the number of time periods included in the model. In either case, a review of all the parameters would be required.

There are two basic methods for modifying the model: by adjusting the parameters, and by changing the structure of the model. There are three reasons for changing parameters:

1. To improve the existing data base;
2. To perform parametric analysis; and
3. To simulate structural changes.

The data base used in the model has limitations due to the accuracy of the sources and the use of general rather than regional data. It is expected that the data base will be improved as the NEA data collection activities continue and as information is acquired from agencies and institutions in Thailand.

When modifying the parameters it is important to determine the accuracy of the new values and the units of measurement. It is important to evaluate the reliability of any source. Where good regional data is not available, general parameters can be used. A major source of discrepancy in the available data on rural energy systems is the use of different units of measurement.

Another reason for modifying parameters is to determine the sensitivity of the model to changes in individual parameters. There are three procedures available for performing parametric analysis. If only a few values are to be adjusted and if the size of the model is not affected, then the parameters can be modified directly in the matrix and the solution from the previous run can be used as the basis for a new solution. This will reduce the cost and the time required.

If the parameters to be modified are indexed and used to compute several elements in the matrix, it is necessary to modify the input files and to rerun the matrix generator. If these changes do not affect the dimensions of the matrix then it is possible to use the previous solution as a basis for the new solution.

If a single parameter is to be modified incrementally over a specified range it is possible to use the LP system software to adjust the specified matrix element and recompute the solution using the previous solution as a basis.

The third reason for modifying parameters is to simulate structural changes in the model. This is more complex. Different activities and their related variables can be removed from the solution by changing the row constraints (RHS) for rows that include these activities or by setting the bounds to zero on the columns that correspond to these variables.

Another method for removing activities from the solution is by setting to zero the coefficients that relate them to the other activities or by increasing the costs associated with these activities.

The model's five components can be decoupled by changing the parameters that describe the resource flows between components. Similarly, new components can be coupled into the model by placing values in matrix elements which are currently zero.

- Structural Changes

The introduction of structural changes in the model is a complex procedure and involves addition of new activities and new constraints to the model in the form of new columns and rows. These changes require that the input files be modified to incorporate the parameters which will define the new rows and columns, and that the matrix generator be modified to read the new data and to construct the revised matrix.

Each modification will reduce the flexibility of the model while making the meaning of its results more difficult to interpret. It is recommended that:

1. Structural changes be limited;

2. Structural changes not be undertaken until the analyst has acquired some skill at working with the current model;

3. Any modification be introduced on a temporary basis until it has proved useful;

4. The original copy of the model be maintained and used as a basis for introducing each new modification.

In the present structure, the household must be self-sufficient in certain food products. These constraints could be eliminated or at least made optional by allowing for purchased rice, meat and animal feeds. The equations in the household component relating to food consumption and those in the animal husbandry component relating to animal nutrients would have to be modified to include purchased sources.

At present there are no equations which constrain the supply of water. If consideration is to be given to establishing a household or village water storage or diversion facility, then the model might be changed to account for the benefits of such a project. These changes would require additional columns to define seasonal water consumption and additional rows to define limits on availability.

If fish ponds, with either fresh or brackish water, are to be introduced into the model, alterations would be required in the labor and food consumption equations in the household component. Also, columns would have to be introduced to decribe the output of this activity and the cost of establishing and maintaining the pond. Alternatively, the concept of fish farming could be introduced in the existing structure by redefining land types to include pond land and by representing the fish as a perennial crop package.

In the present structure there are four sources of fuelwood:

1. Sellers of commercial fuelwood;
2. Woodlots planted with high yielding species on the uplands or nonagricultural land;
3. Natural forest areas; and
4. Existing wooded areas located adjacent to fields, streams, roads or on marginal village land.

Only the first three have been included in the model. If the fourth source is felt to be important, an additional type of land could be introduced into the model to account for this source. Alternatively, existing land types could be subdivided by specifying a certain amount of that land type as being assigned to a low-yield wood crop.

A similar problem exists in the allocation of the land around the house. There are structural and parametric ways of dealing with this problem similar to those mentioned for village wooded areas.

The agricultural component in its current form does not include expenditures on agro-chemicals other than fertilizers. These could be included as separate cost parameters in the definition of each crop package and in each change in the model structure, or they could be netted out of prices of the crop and the processed products.

The energization of agriculture is currently limited to land preparation and to crop processing. Other activities, (e.g. harvesting, threshing, and spraying) can also be performed using non-human sources of energy and would have to be introduced through structural changes in the model.

The introduction of non-patio, crop-drying activities can be significant consumers of biomass fuels. If these activities have regional importance, they can be introduced as new columns in the matrix with fuel consumption parameters connecting then to the agricultural and energy conversion components or they could be introduced as a form of crop processing with the demand for energy specified not as shaft power but as heat.

Home industry and rural industry are not included. These could be incorporated into the model on an activity-by-activity basis with linkages established to the equations defining household self-sufficiency requirements.

The sale of surplus labor is currently included in the model with a fixed wage attached. In order to capture the price dynamics it would be necessary to introduce a wage parameter for each season. Unless it is determined that the competition of external markets has a significant effect on the allocation of household labor, it is sufficient to treat the wage rate as a sensitivity parameter which has a single value throughout the year. The model already captures the sale of labor in different time periods.

The crop processing activity and its shaft power requirements occur in one time period while the residues are considered to be available throughout the year. If it is important to distribute the demand for crop processing over several time periods, the structure of the model could be adjusted to accommodate a fixed proportion of the crop processing in each time period. The year-round availability of residues is limited by a utilization factor which accounts for losses prior to the actual use of the residues. Field residues are usually plowed under as a fertilizer, while harvested residues and process residues are assumed to be kept in storage until they are needed. The complexity of the structure required to track the inventory of residues from time-period to time-period makes it an infeasible modification.

The model's method for treating community resources is limited by its focus on the individual household. There are no easy structural or parametric changes that would permit inter-household competition for village resources to be brought into the existing model.

No allowance has been made for the adjustment in yields with a change in inputs, such as irrigation and fertilizers. This complexity is not justified since the model focuses on the use of energy.

B. RURAL COMMUNITY DEVELOPMENT MODEL (RCDM)

General Structure

The Rural Community Development Model (RCDM) is divided into five components:

1. End Products/Services Goal;
2. Intermediate Products/Services;
3. Energy Conversion;
4. Rural Intermediate Energy; and
5. Internal and External Resources.

The End Products/Services Demand Goal Component

The end products/services demand goal is a set of levels of products to be produced and services to be rendered by a community. This is similar to the end use demands in the EMP model. In each community, one could project a products/services goal at intervals, e.g. each year, every five years, etc.

The goal is divided into: agricultural products, animal and fishery products, industrial products, and services. The agricultural products include selected economic or major crops of the community such as paddy, maize, vegetables, cash crops (e.g. cotton, jute, tobacco, fruits), etc. Animal husbandary and fishery products include meat (e.g. pork, beef), fish, milk, eggs,etc. Industrial products include food products (e.g. rice, the milled grains, cassava, red sugar, dried fish), wood products (e.g. timber, charcoal), household products, and others. Services include transportation, commercial activities, school, etc.

The Intermediate Products/Services Component

Intermediate products/services are those raw materials to be converted to end products/services through processes (if necessary). For example, paddy may either become rice if it is milled or still be paddy if it is sold to market outside the community.

Intermediate products/services include agrticultural products (e.g. paddy, cassava, sugar cane, vegetable, grass, eucalyptus, dipterocarp, maize), animal and fishery products (e.g. pig, cattle, bullock), passenger transport,commercial activities, and others.

The Energy Conversion Component

The energy conversion component allows the conversion of the end-use energy demands to demands in intermediate energy forms. Intermediate energy could be supplies from either external sources or from sources within the community.

The Rural Intermediate Energy Component

Rural intermediate energy includes energy in intermediate forms required by energy conversion components to produce products, to render services for household and public uses. This includes collected fuels (e.g. fuelwood, field residue, crop pocessing residues, dung), process energy (e.g. charcoal, biogas, biomass, solar, wind), commercial energy (e.g. petroleum products, electricity), and animate energy (e.g. human labor, draft animal).

The Internal and External Energy Resource Component

Energy from external sources includes petroleum products (e.g. LPG, diesel, gasoline), transmitted electricity, lignite, etc. Energy to be supplied from sources within the community includes fuelwood, biogas, biomass, mini-hydro, wind, solar, etc.

Resources could be either internal or external resources. Most resources are limited and create the "constraints" of the linear programming problems of this study, (such as the limitation of land, water, person-power, animals, etc.).

Internal resources are the resources available in the community such as land (e.g. lowland, upland, village pasture, and forest). External resources are the resources required from sources outside the community such as petroleum products, government budget, electricity, etc. Some external resources, such as government budget, are limited.

The Rural Community Subsystems

Rural community activities are classified into subsystems. Components, as discussed, are included in each subsystem wherever appropriate. The rural community subsystems are grouped as follows:

- o Basic Rural Community Subsystem Group
  - Land
  - Household (or Rural Community Labor)
  - Agriculture
  - Animal
- o Energy Subsystem Group
  - Energy Supply and Demand
  - Biogas/Fertilizer
- o Small Industry Subsystem Group
  - Rice Processing (or Rice Mill)
  - Animal Processing (or Slaughter house)
  - Spindling/Weaving
  - Mat Weaving
  - Pottery
  - Handicraft
  - Tobacco Curing
  - Rubber Processing

- Fermented Tea Processing

- Community Development Subsystem Group

  - Irrigation/Water Resource
  - Fast-growing Tree
  - Village Fishery
  - Upland Rice Growing
  - Soil Development
  - Rain-fed Rice Growing
  - Mulberry Plantation & Silk worm Farming
  - Second Cropping

- Services

  - Transportation
  - Commercial Services
  - Government Services

A linear programming model was developed to maximize community income under study for given end products/service goals and resource constraints. Flow diagrams were developed, similar to the RES in the EMS, to provide better understanding of the model developed.

To be consistant with other national planning procedures, the procedure for determining Community Income in this study followed the one employed in dertermining National Income by the National Economic and Social Development Board (NESDB).

For a set of end products/services, resources were drawn through links of the model network. Some process links would generate income to the community such as conversion of paddy to rice through the milling process, small industry in the community, introduction of new energy technology (e.g. biogas, biomass, solar). All increase values of resources available in the community and also become income to the community.

The FINERG Software

FINERG software, used in the EMP, was used in this study to provide systematic formulation of the Rural Community Development Model. Using FINERG Software, NEA staff members (already familiar with the EMP) were able to handle the newly developed RCDM without much difficulty. This is an advantage for future modification and/or expansion of the model.

FINERG Software is equipped with a conversion table to convert parameters from one dimension to another. This allows changes in the economic parameters used in the model when the model is used for different communities having variations of value parameters.

The RCDM model has been developed within the framework, capability and capacity of the FINERG software.

ANCILLARY parameters allow the FINERG software to connect flows in processes to the point where the flow has to be produced. BY-PRODUCT

parameters allow the FINERG software to connect the generated by-products to the processes where they are used.

The Components and Coefficients of the Model

Parameters and data for the model developed were obtained from various sources such as the:

- NEA 1980 Rural Energy Survey;
- Base Line Energy Survey;
- Village Energy Model;
- Rural Energy Use Model; and
- Agriculture Statistics.

For the two sample case studies, data were obtained from the NEA's survey and from the observations of the study team during their short visit to the villages. In cases where the data obtained from the survey were inadequate, data from secondary sources were used.

- Land Subsystem

Land (after deduction for household use) is available for community activities. Land is classified into upland, lowland, pasture land, and natural forest. Upland and lowland can be used for cultivation. Cultivation may take place in the wet and dry seasons depending on crops and geographical area. Pastureland could be used for animal husbandry. Natural forest depletes at a normal rate and can be controlled by allocation of land types over the planning period.The available natural forest yields fuelwood to the community. Upland, lowland, pastureland, and land for household uses can be used for the fast-growing tree project.

Since available land types vary from community to community, land areas based on the NEA preliminary survey on Nongwang village were used for the hypothetical model.

The total land area at Nongwang village is 9,000 rai. After deducting the residential area of 200 rai, the total available area of land for other uses is 8,800 rai. Estimated area for pasture land and forest land is 100 rai and 1,522 rai, respectively. Therefore, the total available area of land for cultivation is 7,178 rai. Based on the 1981 national average, approximately 87 percent is lowland. Therefore, in the hypothetical run, the estimated total area of lowland is approximately 6,245 rai and the total area of upland is 933 rai.

- Household Subsystem

The household subsystem includes people in the community by classifying them into skilled labor, potential skilled labor, unskilled labor, children, and retired persons. The potential skilled labor includes the people who could be trained (perhaps by a development program) to be skilled labor.

People in a community basically require transportation, energy (e.g. shaft power, lighting, cooking for seasons), agriculture products (e.g. vegetables, crops), processing products (e.g. rice, meat, pork), animal products (e.g. eggs,milk) and clothes.

Skilled and unskilled labor available for economic activities are derived from people in the domestic community and from other communities as well. People in the community could also work outside the community (exported). This labor is available in seasons for agriculture, animal husbandry, processing and fertilizer subsystems.

Population in the community was estimated from the NEA preliminary survey on Nongwang village, assuming 2 per cent population growth.

Household consumption/requirements (e.g. shaft power, lighting, rice, etc.) per capita were estimated from available statistics and some were assumed. Allocation of labor for the wet and dry seasons was performed by fixing values in the conversion table (for convenience in changing length of seasons for communitites). The imported labor wage rate for seasonal skilled and unskilled labor was assumed.

Seasonal skilled and unskilled labor from a community are available (as ANCILLARY parameters) for agriculture, animal husbandry, processing, energy, and fertilizer as well as for export.

Availability of labor types--skilled, unskilled--for the wet and dry seasons was allocated in proportion to the number of days in the seasons. For the test run, the surplus of both skilled and unskilled labor was assumed to be exported at no value. Import of skilled and unskilled labor was assumed.

Using national statistics the study team classified population into types based on educational level and age.

It was assumed that children will work less than adults. Child work was estimated at 32 days a year compared to 300 days a year for an adult. Consumptions per capita were estimated. Household energy (e.g. shaftpower, lighting, electricity), and transportation requirements were also estimated.

o Agriculture Subsystem

The agriculture subsystem includes crop growing activities. Ten major crops (i.e. paddy, glutinous paddy, maize, cassava, sugar cane, kenaf, vegetable, soy beans, mung beans, and ground nuts) are included in the model. Five additional crops were selected and added to the model to provide more flexibility for the study if a community grew crops other than the ten major crops.

Growing paddy requires unskilled labor, energy (for land preparation, growing, harvesting and threshing), land (i.e. lowland and upland), water, and fertilizer (i.e. nitrogen, phosphate, and potassium). Transportation is also required to transport the harvested product.

The agriculture products would be either consumed within or sold outside the community (exported). Products may be imported into the community if there is a shortage. Products could be directly consumed or sent to processing (paddy may be sent to a rice mill to be processed for rice). Field residues could become inputs to biogas/fertilizer, animal feed, and energy subsystems.

Selling prices and purchasing prices of agricultural products vary from community to community. Data from field surveys were required. To test the model, the prices were taken from the national average.

Since it was assumed that agriculture products could be either exported or imported, average distances in transporting products are required from future field surveys. In the hypothetical case, these data were assumed.

Since there exists a positive relationship between fertilizer use level and crop yield, three possible levels of fertilizer use were incorporated into the model to establish different marginal increases of production. The crop yield response to fertilizer--nitrogen, phosphate, and potassium--would increase at a decreasing rate until the marginal yield became zero. Data used were obtained from the Division of Agricultural Economic Research, Office of Agricultural Economics.

Marginal yield responses for rice were calculated from a formula used by the International Rice Research Institute:

$$Y = 2080 + 15.57*N - .234*(N**2)$$

where, Y = yield in kilogram/hectar
N = nitrogen used
(in kilogram/hectar)

Marginal yields of each type of fertilizer at levels for other crops were determined based on experiments conducted by the Ministry of Agriculture and Co-operatives. Crop yield response to fertilizer was calculated.

Typical crop cultivation is based on rainfall. Irrigation may not be required if rainfall provides more than the minimum water required for the crop. At the minimum water requirement level, a farmer would obtain a minimum crop yield per rai. Additional water, distributed through an irrigation system (with or without pumping), will increase yield until the marginal yield becomes zero. Maximum yields of crops were obtained from 10 years of statistical data published by the Ministry of Agriculture. For a given maximum crop yield and maximum and minimum evaporation of crops, the minimum crop yield could be calculated from the following formula:

$$(1-Ya/Ym) = ky(1-ETa/ETm)$$

where, ky = water response factor
Ym = maximum yield per rai
ETm = maximum evaporation
ETa = actual evaporation
Ya = actual yield per rai

The response of crop yield to water used is a straight line and was incorporated into the model in a manner similar to fertilizer. A ten year average of rainfall statistics in Agriculture Economic Zone 1 was used.

Obviously, the cultivating period of crops varies from region to region. For the hypothetical model, most cropping was assumed to be in Agricultural Zone 1 and the cultivating period of crops was based on the Ministry of Agriculture report. The rainfed water cultivating period for cropping was based on the rainfall statistics in the report.

Maximum and minimum water required (in m.m.) for crops were first determined. Maximum yield responses to the maximum water required for crops were derived from statistics over the past ten years for maximum yields of crops. For a given water response factor (ky) and yield response to water equation, minimum yields of crops in seasons were calculated.

Based on rainfall available, minimum and maximum requirements for irrigated water (both in m.m. and cu.m./rai) were calculated.

The minimum requirements for irrigated water per kilogram output of crops in both seasons were determined. Calculation of marginal requirements for water and marginal yields were calculated. Yields response to water were, therefore, determined.

The use of power in agriculture (in Hp-hr/rai) was compiled from NEA 1980 rural energy survey data.

Allocations of human, cow and buffalo power used for land preparation, growing, harvesting and threshing were estimated from reports prepared by the Ministry of Agriculture.

Allocations of machinery used for growing and harvesting/threshing were based on machine hour use in the activities for crops as reported by the Ministry of Agriculture. The allocation is used to estimate hp-hr (for the activities employing the estimates) on machinery used. The information was derived from the NEA 1980 Rural survey.

Use of energy in agriculture activities (i.e. land preparation, growing, harvesting and threshing) and the allocation of sources of energy were determined. Note that data on machinery used in growing are not available separately, but are included in harvesting and threshing. Energy used in activities (in Hp-hr/ton) were also determined.

In the hypothetical model average land use (in rai per ton) was estimated from 1979-1983 national statistics. Estimates of crop residues were obtained from several sources.

- Animal Husbandry Subsystem

In general, animals are used as livestock, to produce products (e.g. milk, eggs, and shaft labor. They also produce residue (dung) as a by-product.

To raise animals, one requires water, unskilled labor, animal feed (i.e. crude protein, metabolizable energy, and dry matter). Transportation is required to transport livestock and animal products to market.

Livestock could be imported, sent for processing in the community for meat, and consumed in the household. Animal products could also be sold or consumed. Cattle could be used as an energy source (e.g. traction) and transportation shaft power. Typically, dung would be used as input for fertilizer and the biogas digester. Import of animals is also possible if it is necessary to the community.

The following animals were included in the system: cow, buffalo, swine, chicken/hen and fish.

The number of buffaloes and cows actually in Nongwang were used; they were 600 head and 300 head, respectively. The numbers are subject to change when the model is used to assess a particular community.

Raising animals requires unskilled labor, water, and animal feed (crude protein, metabolizable energy and dry matter). The rates of the requirements are given below.

Animals are used for livestock, producing milk, and labor, as appropriate. Allocation of the uses of animals was assumed. Animal outputs--livestock and milk--are available for export and processing (for meat).

Animals produce dung as a by-product. Estimates of dung collected from animals were determined.

Animal feed provides digestible crude protein, metabolizable energy, and dry matter to the animal husbandry subsystem. These are basic daily requirements for animals in order to maintain their ability to work or produce products. The dry matter required is bounded by the amount that an animal can consume. Grass from pastureland, agricultural products, and residues provide digestible crude protein, matabolizable energy and dry matter for cows and buffaloes according to the conversion factor developed for the model. The quantity of digestable crude protein, metabolizable energy and dry matter available from bran, and vegetables for a pig was estimated from the Meta Systems report.

It is estimated that 240 kilograms of grass from one rai of

pasture land will be available for cows and buffaloes as animal feed. Residues from cassava and paddy as well as bran and vegetables are animal feed for pigs.

These animal feeds provide crude protein, metabolizable energy and dry matter for animals which are given above. It is also estimated that a 0.5 person-hour is required to collect grass for animal feed.

- Small Industrial Subsystem - Rice Mill

The industrial subsystem converts raw materials (intermediate products--including minerals) available in a community to end-used products. This requires labor and energy for the conversion process. The end-use products require transportation to deliver products to consumers both inside and outside the community. Alternative technologies could be employed for each industry.

A rice mill operates in both the wet and dry seasons. The by-products of rice processing are husk, hull, bran and processed residues. The processing activity needs paddy as a major raw material, labor (skilled and unskilled), and shaft power. In addition, transportation is also considered in processing rice as a means to deliver the final product to consumers. Three technologies for rice mills are provided. In some communities, paddy may be imported to be used for rice milling.

Rice is consumed by the domestic household or exported. Process residues are used as data input to energy, animal feeds, and other industry subsystems.

Three types of rice mill (small, medium, and large) were considered. Unskilled labor, shaft power, investment costs, operating costs, residues (husk, hull, and bran) for small and large size rice mills were estimated. The medium size parameter values were interpolated.

The price of rice in a community was estimated from NEA's preliminary survey on Nongwang Village and was estimated at 5,600 baht a ton. In the hypothetical model it was assumed that import purchase price and export selling price were the same.

- Small Industry Subsystem - Slaughter House

Animal Processing (slaughter house) could be considered as an example of a small industry subsystem. Animals (e.g. cow, buffalo, pig, swine and chicken) would be the inputs to animal processing. The processing would require both skilled and unskilled labor. Similar to many other subsystems, transportation is required.

The outputs from the animal processing subsystem are meat and hides. Both of them could be exported. Meat can be consumed by households in the community.

Animals and meat could be imported to fulfill requirements of

animal processing and household consumption.

The average weights of a cow, buffalo, and pig were estimated from agricultural statistics. Meat conversions were based on conversion factors developed for this model. Estimated life of animals and labor required were also estimated values.

Purchase prices and selling prices for exported and imported meat as well as transportation required were assumed and subject to change when village data are available.

- Biogas/Fertilizer Subsystem

Fertilizer can be produced from residues--mainly from agriculture (unharvested and harvested) and animals (dung). All chemical fertilizer is imported. Producing fertilizer from residues requires skilled and unskilled labor. Dung can be used directly as fertilizer or as input to a biogas digester yielding sludge for fertilizer and biogas for energy. Fertilizer provides nitrogen, phosphate and potassium for crop growing in the agriculture subsystem. Transportation is required for delivering raw materials, purchased chemicals, and domestic produced fertilizer.

Parameters that were incorporated into the model are as follows:

- Contents of nitrogen, phosphate and potassium in crop residue and dung are estimated based on the HEM.

- Biogas digester yields sludge having same content of nitrogen, phosphate and potassium as that of dung.

- Biogas digester investment cost and operating costs are estimated according to the HEM. Note that the digester yields biogas at the rate 0.25 cu.m. per kilogram of dung.

- Chemical fertilizers are also imported to meet community demand. Contents of nitrogen, phosphate and potassium in chemical fertilizer are estimated from agricultural statistics.

- Labor required in proceesing the biogas digester is estimated at 0.08 hour per cu.m. of biogas output.

- Energy Subsystem

Rural community energy is related to activities in other subsystems. All activities require energy in different forms.

Energy demands in households and services are for cooking, lighting, shaft power (for household water pumping, etc.), and heating. Agriculture and irrigation subsystems require traction, threshing, and shaft power. The processing subsystem requires shaft power to convert raw materials to finished products.

The major energy conversions for cooking are electric cooker, LPG

stove, wood/charcoal stove, and husk/residue stove. These require fuel/energy such as electricity, LPG, wood fuel, charcoal, husk, and residues.

Lighting in a typical rural community utilizes kerosene lamps, fluorescent and incandescent lamps, and calcium carbide lamps (for fishing and small animal hunting at night). These require biogas, LPG, kerosene electricity, and calcium carbide.

Gasifier engine, sterling engine, steam engine, gasoline engine, diesel engine, electric motor, and windmill are energy conversions in providing shaft power. These require biogas, gasoline, diesel, LPG, and electricity for fuel/energy.

Animal labor (buffaloes and cattle) provides power for traction and threshing. Tractors (e.g. two-wheel tractor, diesel tractor) provide traction power by using gasoline, diesel, and LPG, and electricity to provide power for threshing.

Petroleum products (e.g. gasoline, diesel, LPG) are imported. Electricity could be supplied from grid (imported), self generating, and photovoltaic. Charcoal is produced from wood and biomass using different kiln technologies. Biogas is drawn from the process using residues and dung as raw materials. Windmill and micro-hydro energy could be considered as household and community development projects.

The energy system could be considered as a conversion process, i.e. conversion of energy in intermediate form to energy in end-use demands. The conversion factors used are given.

Parameters that were incorporated into the model are as follows:

- Investment and technical coefficients of cooking stove types are from investigation and estimation.

- Investment and technical coefficients of lamp types are from investigation and estimation.

- Investment and technical coefficients of shaft power engines are from investigation and estimation.

- Purchase prices of petroleum products and electricity are estimated.

- Investment and technical coefficients of tractor types are from investigation and estimation.

- <u>Fast-Growing Tree Subsystem</u>

Fast-growing tree projects increase the forest area to produce forest products--specifically, wood. In the rural area, wood is used directly as fuel, wood for energy/fuel, and as raw material for charcoal processing.

Wood is an input to the energy and processing subsystems. Wood products are generated from the forest. The fast-growing tree project increases the forest area, and subsequently increases the quantity of wood. The project requires land (i.e. upland, lowland, and pasture land), unskilled labor from the household subsystem and traction power from the energy subsystem. Five species of fast-growing wood are provided in the model for selection.

The forest subsystem yields wood for the energy subsystem. Wood yield per rai varies from place to place depending on types of natural forest land. For example, wood yield per rai of a sample village at Sakon Nakorn was 0.4 cu.m. per rai, compared to the national average of 0.375 cu.m. per rai.

Fast-growing tree projects require land of several types--upland, lowland, and pastureland--from the land subsystem. The average wood yield from the managed fast-growing tree project was estimated to be 3.2 cu.m. per rai.

Collection of wood requires 0.01 person-day per cu.m. of wood collected.

- Irrigation/Water Resources Subsystem

The irrigation/water resources subsystem provides agricultural water to the agriculture subsystem. Water, in the wet and dry seasons, could be obtained from natural resources. Development programs (e,g, construction of village pond, weir, etc.) as well as micro-hydro projects would increase availability of water to a community. Water may be distributed through an irrigation system with or without pumping. If water pumping is required, shaft power would be supplied from the energy subsystem.

This study considers that rain water would be directly used in the agriculture subsystem. Water resources are divided into two categories--natural flow (such as river, stream, etc.), and reservoir (such as village pond, etc.).

Availability of water from natural resources varies in the wet and dry seasons. The availability is determined by multiplying the number of days in a season by the average flow (in cubic meters per day) in each season. The water from this resource is a source of unelevated water. In certain seasons unelevated water requires pumping.

The reservoir category is divided into unelevated and elevated. An unelevated reservoir is a village pond, swamp, etc. The unelevated reservior captures rain water in the wet season. Availability of water from this source in the wet season is calculated by multiplying the total area of unelevated reservoir by the average annual rainfall (in meters). For example, the three year average annual rainfall at Sakon Nakhon is 1,789 m.m. or 1.789 meter. This would provide unelevated water of 2,862.4 cu.m. per 1 rai (1,600 sq.m.) of unelevated reserviour.

Availability of water from an unelevated reservoir in the dry season is determined from reservoir capacity (in cu.m.). The figure is adjusted by a full-capacity factor (e.g. 0.9) and assumed loss factor of 0.33. For example the water availability from the source would be 0.603 cu.m. per 1 cu.m. of the reservoir capacity.

Total availability of water from an elevated reservoir is determined in a similar manner. The total availability is considered as the source of unelevated water. However, some part of the availability could be also considered as elevated water which requires no pumping. The elevated water available is calculated from total availability of water from this source multiplied by the ratio of average level of water above ground level and average depth.

The total gross availability of water, then, is the sum of unelevated water available (which requires pumping) and elevated water available (which requires no pumping). Taking away the loss in the irrigation system estimated to be 0.33, the net water available is the gross availability of water multiplied by 0.67.

To use unelevated water, the pumping power drawn from shaft-power (in the energy subsystem) of 0.02 hp-hrs per cu.m. is required.

- Transportation Subsystem

Demands for transportation come from household traveling within and outside the community and transportion of raw materials and produced goods from agriculture, processing, animal husbandry, and fertilizer/biogas subsystems. Types of vehicles/vessels as the means of transportation in this study include axle, mini-bus, truck, boat, motorcycle, etc. Each type requires different inputs, for instance, axle transport requires animals (buffaloes and cattle) for which supply varies by season.Fuels used for vehicles/vessels are gasoline, diesel, and LPG. Skilled and unskilled labor are required to provide transportation services. The availability of labor varies by season.

Parameters that were incorporated into the model are as follows:

- Most of the data on the average number of persons per vehicle are not available except on the mini-bus. The unavailable data are assumed from investigation.

- Most of the data on the average load of vehicles are not available except for the mini-bus and truck. The unavailable data are assumed from investigation.

- Cost of investment in the transportation sector is estimated from investigation.

- Energy consumption in the transportation subsystem derive from references (when coded) and assumptions (when not coded).

- Development Project Subsystem - Small Industry

The small industries included in the model are: spindling and weaving, mat weaving, pottery, handicraft, rubber processing, tobacco curing, and fermented tea processing.

(a) Spindling and Weaving

Cotton bowl may be available within the community or has to be imported. Cotton bowl will be spindled for thread and used as raw material for weaving.

Based on information obtained from the Industrial Promotion Department, one kilogram of thread requires about 2 kilograms of cotton bowl. Cost of cotton bowl, if purchased, is approximately 16 baht per kilogram.

The thread can be sold at approximately 90 baht per kilogram. The spindling requires approximately 4 person-hours of labor per kilogram. Total investment cost for the required equipment is approximately 300 baht.

One kilogram of thread is used to produce 7.5 sq.m. of cloth. Purchase price of cotton thread is 200 baht per kilogram. Selling price of cloth is approximately 50 baht a sq.m..

One sq.m. of cloth requires labor of 0.67 person-day or 5.3 person-hours. The total investment cost of required equipment for weaving is approximately 3,500 baht.

(b) Mat Weaving

It is assumed that marsh plants are available at no cost. However, labor is required for its collection and is estimated to be 0.1 hour per kilogram. It is estimated that one kilogram of marsh plant is required for 9 sq.m. of mat output. Mat weaving requires thread and coloring, the cost of which is estimated to be 6.33 baht per sq.m. of mat.

Labor required is estimated to be 1.11 person-day or 8.89 person-hours per sq.m.. Total investment cost is approximately 600 baht. The estimated selling price of mat is approximately 83.33 baht a sq.m..

(c) Pottery

It is assumed that material required for pottery is available at no cost. One kilogram of pottery requires 1.7 kilograms of input material (taking into account an average of 30 percent defective material). The wood required as fuel for heating is estimated to be 0.024 cu.m. per kilogram of pottery output.

Labor of 1.60 person-hour per kilogram is required. It is estimated that a furnace would be used about 18 times a year. Investment cost is estimated to be 16,800 baht for a furnace of

500 kilogram capacity. The selling price is approximately 9.28 baht per kilogram of pottery output.

(d) Handicraft

Since there are many types of handicraft, making a set of tables on which to place the Buddha image (6 inches in size) was selected as the case example.

To make a set of wooden, gold painted tables requires approximately 104 person-hours of skilled labor to complete. The cost of materials is estimated to be 650 baht a set (500 baht for wood, and 150 baht for color ingredients and gold) excluding the cost of labor of 1,000 baht per set. Investment is minimal and negligible. The set of tables could be sold for 2,100 baht.

(e) Rubber Processing

Rubber trees are grown mostly in the southern and eastern part of Thailand. It is estimated that about 80 per cent of the rubber tree plantations are in the South.

The yield of the new breed of rubber tree is estimated at 250-300 kilograms per rai per year compared to the yield of the old one of only 60-80 kilograms per rai per year.

The new breed of rubber tree has been introduced to replace the old one. According to the NESDB's Southern Development Center, 3,376,000 rai (out of a total of 8,935,132 rai) of the old breed of rubber tree were replaced with the new breed during 1961-1982. It will take approximately 6-7 years for the new rubber trees to yield rubber. It has been reported that approximately one million rai of the new breed of rubber tree have provided the higher yield. The rubber tree is slit from January to March (about 150 days a year).

Based on data obtained from the NEA survey, approximately 45 rubber plants can be grown on one rai. The estimated time required to slit rubber trees is 22.5 minutes per rai. Accordingly, approximately 7 person-days per rai per year (in 150 day duration) are required for the slitting (25 person-days per ton output of new breed of tree, or 100 person-days per ton output of old breed of tree).

It was estimated that 7 seconds per rubber plant is required for the collection of rubber latex, or about 1.64 person-days per rai per year. Therefore, collection would require approximately 6.3 person-days per ton and 24 person-days per ton to collect latex from the new breed and old breed of rubber tree, respectively.

It takes approximately 12.7 person-days to process a ton of raw rubber from rubber latex. The selling price of raw rubber is

estimated to range from 12.90 to 14.40 baht a kilogram.

(f) Tobacco Curing

Tobacco leaves are cured by various methods depending on variety. In the northern provinces like Chiang Mai, Chiang Rai, Lampang and Prae, the Virginia variety is planted. Virginia tobacco is also found in the Northeast, though sun-cured Turkish is more common in this region.

The curing process of Virginia tobacco requires the construction of curing stoves, with a holding capacity of 3,000-4,000 kilograms. These stoves cost approximately 140,000 baht each. About 8-10 kilograms of tobacco leaves yield 1 kilogram of cured tobacco. The process is so labor and energy intensive that it requires labor of .03 hr per kilogram and energy of 28 mcal per kg. The heating process relies mostly on fuelwood and, in some areas, lignite is also used. However, the introduction of LPG in the curing process has been proposed.

(g) Fermented Tea Processing

A fermented tea tree has a 50-year life with its maximum yield around the 20-year period. Yield is estimated to be 456.76 kg/rai. The cost of growing is not available, but was assumed to be negligible.

Data from the NEA survey indicate that 47 kilograms of processed leaf require 46.72 kilogram of raw leaf. Labor requirements are estimated for collection, processing, and wrapping.

The processing requires wood of 0.65 kg. per kg. of raw leaf. The investment cost is estimated to be 500 baht for the capacity of 47 kilograms output per day. The estimated maintenance cost is 23.08 baht a year. Price is estimated to be 5-7 baht per kilogram, with an average of 6 baht/kilogram.

- Development Project Subsystem - Agriculture

The agricultural development projects included in the model are: Village Fishery, Mulberry Plantation and Silk Worm Farming, Soil Development, Upland Rice Growing, Rain-fed Rice Growing, and Second Cropping.

(a) Village Fishery

Pastureland with natural water resources is used for village fishery. A ton of output (fish) requires .043 rai of pasture land, 200 person-hours of unskilled labor, 750 kg. of bran and an equal amount of grass.

Fish are consumed in the household and the rest is exported. The sale price of fish is estimated to be 35.26 baht per kilogram.

(b) Mulberry Plantation and Silk Worm Farming

A mulberry plantation requires land of about one rai per ton. It is estimated that labor required for the plantation is 5.5 person hours per ton of mulberry leaf output.

To produce one kilogram of silk thread, about 107 kilograms of mulberry leaf are required. Investment cost is estimated to be 12,000 baht/kg/day. Labor of 80 hours is required for the production of a kilogram of silk thread production.

Silk thread is used for weaving of cloth. A kilogram of silk thread is used to make 2.986 sq.m. of cloth. Necessary equipment for the weaving cost 1,706 baht/sq.m./day. Life of the equipment is estimated to be 3 years. The estimated variable cost in producing the cloth is 10.76 baht per sq.m. A sq.m. of cloth can be sold at 263.10 baht.

(c) Soil Development

The soil development project improves the properties of acid soil or salt soil to increase rice yield. Using 1.22 tons of lime per rai would increase the productivity of the soil approximately 1.5 times.

(d) Upland Rice Growing

The upland rice growing project involves providing appropriate seed for upland cultivation. This increases rice yields 1.33-1.5 times.

(e) Rain-fed Rice Growing

Rain-fed rice growing also involves providing appropriate seed to farmers to increase the rice yield by approximately 1.5 times.

(f) Second Cropping

The second cropping project involves the promotion of use of land for cultivation after the major cropping in the rainy season is harvested. The crops for second cropping are paddy, maize, soy beans, mung beans, ground nuts, and sorghum.

- Service Subsystems

The two service subsystems considered here are commercial services and government services.

(a) Commercial Services

Commercial Services could be incorporated into the Household

Subsystem. From statistical reports of Changwat Sakon Nakhon, only 2.4 percent of the labor force is engaged in commercial services. Therefore, this figure was used for fixing the maximal allocation of the labor force engaged in commercial services.

(b) Government Services

Government services could be incorporated into the Household Subsystem. From statistical reports of Sakon Nakhon province, about 0.6 percent of the labor force is engaged in government services. Therefore, this figure was used for fixing maximal allocation of the labor force engaged in Government services.

Results of Preliminary runds

A Case Study of Nongwang

Nongwang was used as a case study in an application of the Rural Community Development Model. Data from Nongwang were used to simulate the development and use of energy resources available in the area along with related economic development. Determination of optimal development strategies (particularly for people's income) and utilization of Nongwang's natural resources were emphasized.

Nongwang is a community in the Sawang Dandin district, Sakhon Nakhon Province. The distance from Nongwang to Sawang Dandin district is about 40 kilometers by road.

Based on the NEA report, the total area of Nongwang is approximately 9,000 rai. It is composed of 1,500 rai of lowland; 3,328 rai of upland; 3,450 rai of forest land; 100 rai of pastureland; 200 rai of housing land use; 22 rai for temples and 400 rai of public reservoirs. Out of 3,450 rai of forest land, 3,000 rai are used for paddy and glutinous rice fields (characteristic of paddy and glutinous rice fields in Northeast of Thailand).

Nongwang has approximately 1,500 people living in the area. The average number of persons per household is 6.0. Population growth is about 2 percent per annum. There are approximately 669 children (age 0-14 years old) who account for 44.60 percent of the total population. There are approximately 831 adults of whom 570 are unskilled laborers.

Most people are farmers. Their major crops are paddy, glutinous paddy, kenaf, cassava and cotton. Vegetables are grown for use by individual households.

The average household income in Nongwang was estimated to be approximately 16,200 baht per year in 1984 (2,700 baht per capita) compared to approximately 5,200 baht per capita for Sakhon Nakhon province in 1982 as reported by the NESDB.

In designing the optimal development strategies for Nongwang, the consultant team considered additional development projects. Further, the

consultant team considered energy related use--particularly fuelwood, commercial fuel, etc.--so that energy aspects of the village would be planned along with the optimal village development stategies.

The model simulation was performed assuming a 3 percent real discount rate. Its results are as follows.

- Case 1 (Base Case): Without Development Project

In Nongwang the average per capita real income for the five year period 1985-1989 was approximately 2,914 baht. Real per capita income of the villagers was assumed to be increasing gradually.

The villagers' main cash income comes from exporting paddy, glutinous paddy, cassava, and kenaf. People make cloth and mat enough for their own use in order to minimize cash expenditure. The rationale for existing activities is for their own particular subsistence.

- Case 2: With Development Projects

Several development projects were considered. They are: digging a public reservoir, growing forest trees, electricity connection, piped water project, textile weaving and spinning, handicraft, fish feeding, mat weaving, pottery, cocoon-silk feeding, and silk weaving and spinning.

It was also assumed that villagers still exported paddy and glutinuous paddy rather than already processed rice and glutinuous rice--largely for marketing reasons.

Adding a development project to the base case showed that the average per capita real income for the five-year period 1985-1989 grew to approximately 5,000 baht.

- Optimal Development Strategies for Nongwang

Based on the model run and the consultant's opinion, optimal development strategies are as follows:

(a) As proposed by villagers, about 320,000 cubic metres of the public reservoir should be dug each year in 1985 and 1986.

(b) Fish feeding in the public reservoir so that villagers would have enough fish for protein and for export to nearby areas was a successful development project tested by the model.

In this project, a villagers' committee is needed to manage the public reservoir feeding fish project. Catching fish in the fish egg laying season was prohibited. Catching fish only twice a year was implemented in order to let the fish grow naturally to full-scale in 6 months.

Since it was a community project, the model, however, allowed villagers to catch enough fish for their own food. The other fish

were used for export to establish funds for the community.

(c) Handicraft and Pottery were not introduced. They should be introduced to villagers by training, starting in 1985.

(d) Mat and Cloth weaving are mainly for villagers' own use and were not significant factors in this case.

(e) Cocoon-silk production, silk weaving and textiles could not yet be introduced because the market price needs to be approximately 20 percent higher than it is to justify expense and labor. Cocoon-silk production particularly is very labor intensive, so much so that it competes with other activities.

(f) Importing some labor in the wet season is needed for farmers who still use the labor intensive farming method. Introduction of farm mechanization was not justified because of marketing and investment reasons. The level of household income is still too low to have enough savings for investment. It was necessary to export labor in the dry season. The government was needed to help create jobs. In 1985 and 1986, jobs created by digging the public reservoir will be sufficient for dry season income.

(g) As proposed by villagers, introduction of electricity in 1987 is reasonable. The market price of electricity is low compared to kerosene, LPG etc.

(h) A piped water project should not yet be introduced because villagers have enough rain water for drinking and cooking. A project for storing rain water should be introduced instead. Education on drinking boiled water should also take place. These efforts will minimize government subsidies in this case.

(i) In 1985-1989, the forest will still be abundant enough for village needs. The government should not subsidize a fast-growing tree project as expected by villagers. Education should be provided instead. Rather, the NEA should introduce efficient charcoal making methods because inefficient village methods need improvement. Scarcity of forest or fuelwood can easily be detected by checking collecting time of fuelwood of villagers.

(j) Another project that should be introduced by the NEA is the introduction of an efficient, low-cost cooking stove.

(k) Since the task of increasing the villagers' incomes with minimal government subsidies is a priority, the forest should be grown beyond 1989.

(l) Biogas production by households is not feasible for individual farmers. Each has too few animals. Grouping the livestock of many farmers would make biogas production for the community feasible.

In conclusion, doubling the per capita income of Nongwang villagers in a five-year period is feasible. The rationale is:

- To fully utilize the public reservoir for natural fish feeding;
- To request government support to create jobs digging the public reservoir;
- To set up a village committee to see to this community project; and
- To request government help to train handicraft workers and potters.

Moreover, an efficient cooking stove should be introduced and training in how to make charcoal should be performed. Other unprofitable projects or costly subsidized projects such as livestock feeding, cocoon-silk production, piped water, and subsidized fast-growing tree projects should be postponed.

- Case 3 : With Development Projects and Export Processed Rice

If marketing is feasible, villagers should export processed rice and glutinuous rice rather than unprocessed paddy and glutinous paddy. This can be achieved by efficient rice milling and good marketing. If it can be done in addition to Case 2, the average per capita income for the five-year period 1985-1989 will increase to 6,022 baht.

- Case 4 : With Export Processed Rice

If Case 3 is implemented without Case 2, i.e., without development projects, the average per capita income for the five-year period 1985-1989 will increase to 3,935 Baht.

- Comments

Some comments could be made on energy-related issues in Nongwang as follow:

(a) Forest Supply

Abundance of forest supply still exists in Nongwang. The cost of fuelwood is approximately equivalent to opportunity cost of labor in collecting fuelwood. Scarcity of fuelwood can be checked by considering labor time in collecting fuelwood. At present, fuelwood in Nongwang is abundant. Labor-time in collecting fuelwood in the dry, rainy and winter season is approximately 0.0044, 0.0059 and 0.0042 person-hours per kilogram of fuelwood respectively. The average round trip distance in collecting fuelwood is approximately 2.25-2.35 kilometres.

The abundance of forest supplies results in inefficient charcoal making methods and cooking stoves. Therefore, efficient charcoal making methods and an efficient cooking stove should be introduced very soon.

(b) Electricity Connection

The Electricity connection proposed by villagers is very rational for electricity is one of cheapest energy resources for lighting. The simulation model shows that electricity will most often substitute for kerosene in lighting. Further, the electricity connection will reduce cash expenditures.

(c) Fast-Growing Tree Project

The Fast-Growing tree project in the public forest is a costly project subsidized by the government. The project should be postponed until villagers have more income. Villagers will collect fuelwood as usual because it is in expensive compared to other energy sources for cooking and the supply is projected to be abundant in the five-year period, 1985-1989.

(d) Biogas

Biogas production by household is not feasible. It is feasible for a group of villagers, but each household has too few animals. Biogas production for the community or group of villagers would be feasible as long as there were some form of organizational management and a demonstrated willingness to participate by villagers. How to establish this community or group effort should be investigated.

(e) Biomass

Biomass is available. Little utilization occurs because of time spent in collection. Collection management should be studied for the introduction of steam engine, and gasifier by biomass (particularly by husk).

(f) Commercial energy

Villagers are very rational. Because of low income, they choose to make few investments in machinery and means of transport. Commercial fuel is imported whenever necessary, although it is slightly more expensive than in town.

- Development Strategies in Nongwang

Design of development strategies in Nongwang for 1985-1989 are discussed below:

To double the income of villagers in five years with minimal government subsidy is feasible. Moreover, the natural resources of Nongwang can be utilized effectively.

The public reservoir project should be implemented first. The government can help create jobs in the dry season by digging the public reservoir one meter deeper than it is and by providing small fish for natural feeding.

Community participation will be used for managing the public

reservoir and natural fish feeding for individual household needs. A village fund should be established for further development.

Handicrafts and Pottery should be introduced by training in 1985. The NEA should also introduce efficient charcoal making and an efficient cooking stove rather than a fast-growing tree project in the five-year period 1985-1989.

Biogas production by a group of villagers or the community should be further studied.

Cocoon-silk and silk weaving should not yet be introduced yet unless the market price rises approximately 20 percent.

Livestock should not be introduced yet. This would be an unprofitable enterprise and use a lot of labor that can and should be released for other activities such as exported labor, handicrafts, etc.

Scarcity of labor in the wet season and abundance of labor in the dry season is typical in Nongwang as well as in the Northeastern part of Thailand. Creation of jobs should help increase villager income through the multiplier effect. In the case of Nongwang, digging the public reservoir deeper in conjunction with natural fish feeding should be supported.

A Case Study of Huay Pui

With the application of the Rural Community Development Model to Huay Pui, the study team attempted to determine the level of output in various economic activities. The investigation also considered economical sources of energy in such a way that community income of Huay Pui was maximized, subject to its major constraint--land. Not surprisingly, the RCDM performed satisfactorily with the available data. The results obtained from the RCDM can be used as a guideline for policy makers to design effective development strategies for the community.

Huay Pui district consists of 7 villages of Tambon Longkhod in the south of Amphoe Praw, Chiang Mai province. Huai Pui is about 70 kilometres from Chiang Mai and about 30 kilometres from Amphoe Praw. Seven villages of Huay Pui are scattered in both sides of a main road connecting Amphoe Praw and Chiang Mai province.

The total area is estimated to be 74,232 rai of which 80 per cent is natural forest, 18 per cent is cultivated area (lowland and upland) and the rest (2 per cent) is pastureland.

At present, there are approximately 4,183 people living in Huay Pui district, or 1,094 households with an average size of 3.8 per household.

Due to unavailability of data, national statistics for the distribution of population were used. It was estimated that about 44.6 per cent of the total population are children aged 0-14 years. People of working age were divided into unskilled and skilled labor.

Like many other rural villages, the agricultural sector plays a very important role in Huay Pui community production. More than a half of the total lowland is utilized for paddy cultivation. Other economic crops in the region are ground nuts, tobacco and garlic. The uplands are used for paddy and ground nut plantations in the wet season.

Compared with areas in the northeastern provinces, yields in other areas are much lower than in Huay Pui. Soil around the Huay Pui district is said to be high in nutrients.

Most people at Huay Pui engage in agricultural activity in both the wet and dry seasons. However, in the dry season, part of the labor force migrates to work outside the community since the opportunity for cultivation is limited due to limited water resources.

Major non-agricultural activities are tobacco curing, rice milling and swine slaughtering. Tobacco curing requires tobacco leaves from inside and outside the community and cured tobacco is exported. Rice milling and swine slaughtering are done mainly for household consumption.

The Huay Pui micro-hydro project, which is under construction by the NEA, has a capacity of 50 KW and will generate electricity 246,500 Kwh a year. Based on NEA figures, the flows of water are 0.037 and 0.316 cubic meters per second in the dry and wet seasons, respectively.

The income from selling the electricity would be allocated to the government and village according to proportion of investment (e.g. 75 per cent to the government and 25 per cent to the village).

Another micro-hydro project is planned for construction by NEA on Mae Khod. According to the plan, the project will have 2 generating units having a capacity of 125 Kilowatts each. This micro-hydro will generate 1.69 million Kwh of electricity a year. The flows of water are estimated at 0.07 and 1.11 cubic meter per second in the dry and wet seasons, respectively (with an annual average of 0.44 cubic meter per second).

Huay Pui can be considered a middle-class income rural area with some degree of urbanization due to its proximity to Chaing Mai.Its nutrient soil yields high income for people engaging in agriculture, compared with low incomes in the northeast.

Model simulation was done assuming a 3 per cent real discount rate. The results are as follows.

- Case 1 (Basic Run)

  The basic solutions obtained from optimizing the income of the Huay Pui district between 1985-1989 yielded a per capita income of 4,505 baht in 1985 and a per capita income increase to 11,357 baht in 1989.

  Community income in 1985 is small compared to the next four periods because of the huge amount of total investment in energy, irrigation and rice milling in 1985 which accounts for more than

18,000,000 baht. Per capita income in 1985 is estimated at 4,505 baht per year or approximately 1,500 baht per household per month. Between 1986-1987, per capita income is averaged to become 10,844 baht per year. The figure is consistent with national statistics of 14,000 baht per year. Most incomes are derived from export of agricultural products with the additional contribution of tobacco curing and unskilled labor export.

The basic solution for each sub-system is discussed below.

(a) Land

As mentioned, data on present Huay Pui production reveal that, with obtained average yield per rai, land is underutilized. In the wet season, the basic run resulted in only 60 percent of lowland utilization in the wet and dry seasons. The expansion of land utilization is not possible due to the limited supply of water. Additional water will add marginal yield per rai rather than an expanded planted area since the latter involves more labor and traction to be used for land preparation. The data show that upland crops utilize about 82 per cent of the total available land. However, upland utilization tends to increase from 82 per cent in 1986 to 100 per cent in 1988. Upland croppings rely only on rainfall.

Natural forests around Huay Pui district are abundant and can supply sufficient fuelwood throughout the period. The model does not suggest additional forest area. However, government policy concerning a fast-growing tree project would still be beneficial--especially in terms of avoiding environmental damage. Also, it may serve as a complementary project for the tobacco curing industries (if other types of fuel are not available since the activity requires a huge amount of fuelwood).

(b) Household

With a 2 percent projected rate of population growth, labor at working age (over 14) exceeded the total labor needed for various economic activities in Huay Pui district. The model revealed the figures of 1,947 exported unskilled laborers in the dry season and of 629 in the wet season. The figures tend to be overestimates for three reasons. First, 300 working days per year per laborer were hypothesized(which is probably high in practice and may result in an underestimation of labor requirements in various economic activities). Second, the model runs did not take into consideration the number of old and retired laborers who work partially for animal raising, weaving and home-made handicrafts. Third, the data for the present, planted area around Huay Pui (obtained from the NEA) are far below the total available area. This results in an underestimated demand for labor. Taking these three factors into account, it is recommended that the figure of exported unskilled labor should be reduced to 630 in the dry season and 370 in the wet season.

(c) Agricultural Sector

The agricultural sector is the major source of community income which contributes more than 85% of the total income. The results suggest that, in the wet season, crops like tobacco, ground nuts and mung beans yield more economic returns than traditional crops like paddy (both lowland and upland) and also yam. This is due to the fact that with the limited amount of water, paddy production (which requires relatively more water supply than other crops) fails to prove profitable; whereas when additional water is added into the production of tobacco, ground nuts and mung beans, the output yields are more marginal. In the dry season, the model suggests more utilization of land in cropping garlic, onions, ground nuts, mung beans and sweet grass. Irrigated water from the elevated reservoir should be used in the production of onions, garlic and sweet grass for higher marginal returns. The production of crops in both the wet and dry seasons during 1985-1989 are given by the model.

(d) Animal Husbandry

Animal husbandry was not demonstrated to be a profitable activity for the community. Animal raising requires many hours of labor and much food compared to the marginal return received from the difference between purchasing and selling value. When no restriction on the amount of animals (cow, buffaloes, swine and chickens) to be raised in the community are imposed, the model suggests that all of the available animals be exported except for a minimum amount of buffalo to be used in the agricultural sector. The results seem to contradict what has been going on in Huay Pui. About a third of the total households raise on the average 2-3 swine, 2 cows and 2 buffaloes per household. The model results are probably due to the fact that the parameter coefficients applied to the model (such as food or labor requirements) are slightly overestimated. In fact, most of swine raised in Huay Pui households usually depend on left-over food and plants rather than on bran and hull. Also, rather than unskilled labor, the women and children of the household are most often responsible for animal raising. The model does not take into account these types of labor to be used in animal husbandry activities; therefore, usual unskilled laborers should be allocated to other activities--especially agriculture--or even exported to work outside the community since they can contribute more to community income that way.

In the wet season, when buffaloes and cows are kept in pens, they yield more dung than in the dry season. In the wet season, dung obtained from available cows and buffaloes is estimated to be about 600 kg per day compared to 490 kg per day in the dry season. This amount of dung yields 321,300 cubic metres of biogas and 7.3 ton of fertilizer per season. The biogas then derived is mostly used for household cooking. The question is whether people in the community can really work cooperatively to utilize this by-product for animal husbandry at a community level. If no

cooperative takes action place, a household tends to waste animal dung on the farm and most of it is used as organic fertilizer.

(e) Processing

Basic food processing activities are rice milling and animal slaughtering. Profitability of rice milling in the community depends mainly on the difference between exported paddy and rice. At the exported price of paddy of 3,260 baht per ton compared to 5,750 baht per ton of processed rice, rice milling is not profitable. The community may be better off exporting their paddy production. If farmers can sell paddy at 3,000 baht per ton and rice at 5,750 baht per ton, rice milling would bring a profit margin to the community. The size of the rice mill should be approximately 18-20 hp since it is less expensive in terms of fixed and labor costs than the small size (12-15 hp) mills.

In Huay Pui, at present, approximately 86,000 kg of pigs are slaughtered for household consumption each year. Cows and buffalo are not slaughtered since people at Huay Pui rarely eat beef.

(f) Fertilizer

The model suggests that in order to maximize community income, fertilizers used in the agricultural sector should be derived from animal dung. In the wet season when more animal dung can be collected than in the dry season, fertilizer could be produced, but in the dry season animal dung should be allocated for biogas production and, instead, rice residues should be used in and out of the field for fertilizing crops. The results suggest that fertilizer should not be imported. This is consistent with the present situation at Huay Pui in which chemical or imported fertilizers are not widely used (reflecting the high nutrient soil and high yield per rai without additional fertilizer). However, these results do reflect limited knowledge of marginal yield responses to two major elements of fertilizer--namely phosphate and potassium.

(g) Energy

Throughout 1985-89, the average demand for energy used as traction power in the agricultural sector was estimated to be 244,000 hp hrs in the dry season and 293,000 hp hrs. in the wet season. This energy demand is met by an animal source--buffalo. Compared with cows, buffaloes seem to be more advantageous. Both a cow and a buffalo require the same amount of inputs for raising, but buffaloes yield more traction power and less human work. In addition, there is a surplus in the total available buffaloes at present and they could be used for traction purposes. Therefore, farm mechanization such as 4-wheel and 2-wheel tractors are not attractive for farmers here--especially those who own buffaloes.

Fuelwood is the major source of energy used at Huay Pui. Apart from the amount (410 tons) of fuelwood used in tobacco

curing, an additional 60 tons is used for household cooking. The reason why fuelwood is still a major source of energy is that the forest is abundant around the Huay Pui district and fuel is easily obtained with little effort and labor. LPG is used for cooking in very few households and a very small amount of cooking is supplied by biogas.

Electricity used in the household for lighting through fluorescent and incandescent light is mainly from micro-hydro generated energy--not from self-generating energy (since the latter is more expensive than the former). In addition, there is the possibility of selling electricity generated by the micro-hydro plant to the area around Huay Pui since there is a surplus supply. Throughout the planning period, the kerosene lamp was less used whereas fluorescent and incandescent lamp became increasingly more important. After 1987, the second micro-hydro plant will be completed and will yield a higher income level to Huay Pui in terms of more electricity to be exported. The exported electricity throughout the period generated from two micro-hydro plants is estimated to be approximately 1,693,200 Kwh between 1986-1989.

For commercial energy, diesel fuel is mainly used--especially for transportation and shaft power. Throughout 1986-1989, about 372,000 liters of diesel fuel are imported, compared to 11,656 liters of kerosene and 7,416 litres of regular gasoline. The figure of imported kerosene may be overestimated due to an overestimation of kerosene lamps used for household lighting. Premium gasoline is proven to be an uneconomical source of energy due to its relatively high price and high degree of substitutability between it and regular gasoline.

(h) Irrigation

Due to limitations of data on available water used in the agricultural sector, the model utilized the data on evaporated water of various crops from agricultural experiments conducted by the Ministry of Agriculture and Co-operatives. Taking the amount of rainfall in Chiang Mai province, the additional minimum water required for present actual plantation was then calculated. The estimated demand for water was about 2,570,000 cubic metres and (under a 33 per cent efficiency loss) the supply of water was estimated to be about 3,835,000 cubic metres of which 48 per cent was supplied by the elevated reservoir around Huay Pui district and the remaining 52 percent came from two main rivers.

(i) Transportation

Data show that axles are less used for transportation at Huay Pui since urbanization has been increasing. Usually, the motor cycle is the most economical means of traveling, whereas a mini-bus is mostly used for transportation of agricultural and household commodities. Trucks emerge as the third most-used

vehicle and diesel fuel is the main commercial energy source with a very small amount of regular gasoline being used in trucks.

(j) Small Industry

Apart from rice milling and swine slaughtering, tobacco curing is the major industrial activity at Huay Pui. Tobacco leaves from the cropping area around Huay Pui and nearby districts are cured. The curing process requires fuelwood and labor to work the curing stoves with a holding capacity of 2500-3000 kilograms. At present, there are few tobacco curing plants around Huay Pui. Tobacco curing activity is proven to yield such a good economic return that the model suggests further investment in tobacco curing (in the amout of 12,490 baht in 1985 and an additional 14,000 baht in 1988) in order to promote tobacco curing at Huay Pui and use up surplus labor in the community.

Throughout 1985-1989, an average of 58 tons of dry tobacco will be produced; this requires, on the average, 1,950 Mcal per year. More than 90 percent of the heat requirements are obtained from fuelwood and the rest may be supplied by LPG or lignite.

The other cottage industry introduced into the model is "spinning and weaving". This was done on a very small scale for household consumption, not for export. Each year approximately 20,000 square metres of cloth are required for domestic use.

In fact, there are a few other insignificant cottage industry activities in the Huay Pui community such as blacksmithing (knife), and handicrafts. But they are very few and done on a very small scale to meet the demands of a very small percent of the community.

- Case 2 : An Introduction of a Gasifier into Huay Pui in 1987

After the basic runs, several sensitivity analyses were carried out in order to answer some interesting questions about the development projects at Huay Pui. Each sensitivity analysis is discussed below.

Comparing income per capita before and after the introduction of a gasifier in 1987 reveals that its introduction can raise household income after 1987 from about 3,783 baht per month to 3,935 baht (or about 4 per cent). An increase in income is caused by an increase in electricity generated and exported to nearby villages around Huay Pui. A gasifier will use husk and rice residues for the heating process. An additional 2,280 Kwh of electricity will be generated apart from the micro-hydro. The community will solely rely on electricity as a source of energy for lighting purposes and the kerosene lamp will fade away through the process of development. Since electricity generated from the gasifier and the micro-hydro plant will exceed the electricity demand of the community, this excess energy provides an opportunity for exporting energy to a nearby district. In fact, a gasifier does

not significantly add income to a household but it is beneficial in terms of convenience and standard of living. However, if the project of a gasifier is carried out, marketability of surplus electricity supply must be assured,otherwise resources may be misallocated since the demand for electricity is still limited to only household consumption and not widely used in other economic activities.

- Case 3: Micro-Hydro Project

This study was aimed at seeing whether a community was significantly better off with the availability of micro-hydro plants. Without micro-hydro plants, the community generates electricity for household consumption, but mainly kerosene lamps are used. Income per capita in 1985 will be reduced from 4,505 baht per year to 3,907 baht. Income of the household will decrease from 1,500 baht a month to 1,300 baht (or by 14 per cent). In addition, without micro-hydro power generation, a windmill project is proven to be an attractive project for power generation.

- Case 4: Irrigation Project

By allowing water to increase by 30 per cent of the total amount, it was found that people will use less river water since use of river water requires pumping and costs more for a household. By providing more elevated reservoirs, additional water will result in an increase in yield per rai. Household income rises from 1,500 baht/month to 1,565 baht (or about 4 per cent). The figure somewhat underestimates the benefit of the irrigation project since the model does not deal with the possibility of expanding the cultivated area. This additional amount of water can only add to marginal yield since expanding land requires traction and labor. Further exploration should proceed in this area.

- Case 5: Farm Mechanization

If the government's industrial district project in the north is undertaken, farm mechanization will result. The aim, in this run, was therefore to see the effect of farm mechanization on income. By introducing farm mechanization in the agricultural sector (that is substituting machine labor for human labor for traction and export) labor is released to work in the industrial sector. However, income per capita does not significantly change. The results show that, by allowing 30 per cent substitutability between human labor and machine, income per capita increases only 2 per cent.

This small increment increase in per capita income is mainly due to the fact that released human laborers were hired outside the community at a very low rate (about 20 baht per day in the wet season) In fact, if the labor market develops as a result of the industrial district project, wages will undoubtedly be higher than 20 baht per day. The government project is beneficial to Huay Pui under the condition that the wage rate is much higher than 20 baht and the labor market can absorb the released labor force from the agricultural sector without deteriorating the wage rate.

- Comments

Some comments should be made on energy related issues in Huay Pui.

(a) Fuelwood

Fuelwood is the main source of energy used in the community. People in rural areas can not afford to buy other fuels. In addition, fuel is locally available and does not require complex equipment to collect. Although charcoal may be a more efficient use of fuelwood, it is still not a solution for replacing fuelwood since it may simply enable people to burn more wood. In this case, a fast-growing tree project will be one solution for rapid exhaustion of fuelwood.

(b) Biogas

The model suggests that animal dung be converted to fuel. However, to develop biogas as a source of energy requires cooperative action in the community; otherwise each household tends to waste it. Biogas can be used for cooking, crop drying or power generation. In addition, biogas will leave valuable fertilizer residues. The problem is that a steady supply of biogas cannot be secured in the wet and dry seasons. The supply of biogas varies by season and feed.

(c) Animal power

Buffaloes are mainly used for ploughing. To replace them with mechanical power would cost more in terms of energy and machinery. Therefore, in rural areas such as Huay Pui where capital is lacking and fuel prices are high, the possibility of farm mechanization should be postponed to the distant future--especially when there is still a surplus labor force. Animal power remains a feasible method for agricultural production.

(d) Micro-hydro Power Generation

The first micro-hydro plant is completed by cooperation among people in Huay Pui. It is useful in terms of electricity supply. When the second micro-hydro plant is completed in 1986, it is expected that the total electricity generated will be sufficient for community demand, and even for export to neighboring districts.

(e) Gasifier and Steam engine

According to the RCDM applied to Huay Pui, a gasifier introduced into the community would be beneficial. It increases community income since the surplus electricity supply can be exported at grid price. However, when comparing the gasifier and

steam engine, both may be considered equally good for the community. But a gasifier may be slighty more advantageous in terms of its residues which can be used in other activities such as mushroom growing. Studies on the usefulness of the residues should be conducted.

- Development Strategies

Development strategies in Huay Pui for 1986-1989 are given below:

(a) Fast-growing tree project

In Huay Pui, like in many other rural areas, cutting trees for domestic fuelwood is a growing cause of serious environmental damage. A challenge for energy policy makers is to find some other energy to replace firewood in rural areas like Huay Pui. With the application of the model, results show that the income of Huay Pui will undoubtedly reduce if serious restrictions on cutting fuelwood are imposed. Although there are a few other renewable energy sources to substitute for fuelwood, the income of the community will inevitably decrease. It is due to the fact that the model fails to deal with the social cost of the environmental damage that occurs when wood is cut. Further study should take into consideration the possibility of quantifying the social cost of using fuelwood, or substituting fuelwood with some other energy source to see whether community income significantly differs.

The study team is aware of the fact that, although the model does not suggest a fast-growing tree project because of the overestimated forest area, the project should be undertaken anyway. Fuelwood is disappearing very fast since people are lopping trees for firewood faster than trees are growing. The FAO estimated that by the year 2,000, 140 milion rural third-worlders will be seriously short of firewood and 2,225 million will be removing the fuelwood resource faster than it grows. Thailand is no exception. As far as private cost is concerned, the problem of disappearing fuelwood may not be serious since rural people may walk further or substitute it with crop residues found around the farm area e.g. animal dung, leaves, crop stalks and others. But, from the social point of view, the problem is escalating because the disappearing forest is hazardous to an agriculture based economy like Thailand in terms of rainfall, climate and fertilizing the soil. Soil inevitably suffers from the loss of nutrition and organic matter after trees are removed.

(b) Industrial Estate Project

According to the National Development Plan's objective of decentralizing the industrial area to other parts of the country besides Bangkok, an industrial hub will be located in Lampoon province. The project will help raise the Huay Pui community income because the project will absorb surplus labor from Huay Pui. The labor market initiated in this industrial hub will

guarantee higher wage rates than that of the agricultural sector.

(c) Irrigation System

At present, Huay Pui underutilizes its available land since limited water resources do not permit opening up new cultivated land. If an irrigation project for an elevated reservoir is undertaken, the Huay Pui agricultural output will undoubtedly increase both by expanding planted area and by increasing the average yield per rai. However, the feasibility of an irrigation project depends heavily on marketability of outputs to be produced Increasing agricultural outputs without a market plan will probably result in deteriorating agricultural prices and the farmer's income remaining the same. The study team therefore recommends simultaneous actions on the irrigation project and on market planning for agricultural products.

(d) Promotion of Agro-industries

At present, the agro-industries at Huay Pui are tobacco curing and rice milling. According to the RCDM model the tobacco curing process yields a profit margin to the community. Rice milling is done on a small scale for household consumption. However, the model suggests that the rice milling process should be promoted, provided that the present rice mill capacity is underutilized. Nevertheless, the possibility of selling processed rice rather than paddy depends heavily on the difference between the paddy price and the processed rice price. Whenever the government guaranteed price of paddy fails to be true, selling processed rice yields higher income for the community than selling paddy. The merit of the rice milling process lies here and, in addition, in the marketability of processed rice.

Another potential agro-industry project is fruit preserving--especially mangoes (which are usually grown in most households). Mangoes are sold to outside sources for preserving in Chiang Mai at slightly low prices.

Setting up an agro-industry such as fruit preserving probably will contribute to community income. When data are available from the recent NEA survey, food preserving should be incorporated into the model as a part of industrial development.

Uses and Potential Modifications of the Model

The RCDM can be a very powerful analytical tool when applied to the types of problems for which it was designed. The specific applications for this model should be developed as the NEA analysts become familiar with the operation of the RCDM, its data requirements and the interpretation of its outputs.

Uses of Model

The following is a general summary concerning the uses of the RCDM.

The model:

- Can measure the demand for unpriced resources which serve as complements or substitutes for commercially available resources;

- Cannot determine the demand for different commercial products as a function of price or of income; this type of analysis is best left to economists working with consumer expenditure surveys;

- Can determine the implicit cost of a technique or technology to the rural community;

- Can determine the shadow prices for various resources used in the rural community;

- Can be used to access a new technique or technology introduced to the community. Where there are competing techniques and technologies and no limited resources, it will always choose the one which has the lowest cost or produces the highest net income. However, within a given resource, the model would select the best combination of techniques and technologies for the maximized community income;

- Can determine the opportunity cost, i.e., reduction in community income, which would result if the community used a technology or technique other than that chosen by the model;

- Cannot make value judgments or predict consumer behavior on a basis other than the maximizing of community income. Such issues involve analysis of consumer preference and the use of utility theory;

- Can make use of forecasts of consumer behavior to determine the implication on the demand for resources in the rural area;

- Cannot project the rate of acceptance of new programs or policies introduced from outside the community;

- Can indicate the cost to the community of programs or policies and the effect on the community's use of resources and level of economic activity if it adopts these programs or policies;

The RCDM is the extended version of the HEM model. Its subsystems are not limited to the household subsystems included in the HEM. The model is designed to cover community environments required in a decision process, such as:

- The community could not be self-sufficient in certain food products. There are options by allowing for purchased rice, meat and animal feeds. The household component relating to food consumption and those in the animal husbandry component relating to animal nutrients have been included as purchased sources.

- There are parameters which constrain the supply of water. In establishing a community water storage or diversion facility, the model is designed to account for the benefits of such a project.

- Fish ponds are introduced into the model. The concept of fish farming could be introduced in the existing structure.

- There are four sources of fuelwood: (a) sellers of commercial fuelwood, (b) woodlots planted with high yielding species on the uplands or nonagricultural land, (c) natural forest areas, and (d) existing wooded areas located adjacent to fields, streams, roads or on marginal village land. All of these have been included in the model.

- The energization of agriculture is not limited to land preparation and to crop processing. Other activities (e.g. growing, harvesting, and threshing) have been introduced into the model.

- Small rural industries are included. These are incorporated into the model on an activity-by-activity basis with linkages established to the model.

- The sale of surplus labor is currently included in the model. In order to deal with price dynamics, the model could introduce a wage parameter for each planning period.

- The model does not focus on the individual household. If it did, this would permit inter-household competition for village resources to be brought into the model.

- Allowances have been made for the adjustment in yields with a change in inputs, such as irrigation and fertilizers.

As discussed in the HEM, the usefulness of a model of this kind depends directly on the skill of the person using this tool. The model is to be used in a dialogue mode, with the analyst asking "what if?" questions.

Potential Modifications of Model

The general structure of the RCDM has been designed to be modified as required for:

(1) The question being asked; and
(2) The region being analyzed.

o Non-Structural Changes

The parameters which can be modified are the community parameters, the regional parameters, the technical parameters and the price and cost parameters.

- The community parameters which are used to model the different socio-economic groups in a region describe the community's access to resources. Modifying these parameters will indicate the effects of resource availability on the decisions of the community regarding energy use and level of economic activity;

- The regional parameters describe the types of crops grown, the time periods of agricultural activity, the use of animals and the types of land available for agricultural and other biomass production. It is important that the inputs be limited to those which are appropriate to the region being studied.

- The technical parameters include the values for physical conversion efficiencies, chemical conversion factors, and energy supply and conversion characteristics, generally based on engineering or scientific analysis as reported in publications.

- The price or cost parameters affect the movement of resources across the community boundary into regional markets, not only between regions but also within regions.

Since the FINERG software generates matrix output to be input of the MPSX package similar to the matrix generator employed in the HEM, methods in modifying parameters are the same as dicussed for HEM.

- Structural Changes

Similar to the HEM, the introduction of structural changes in the model is a complex procedure and involves the addition of new subsystems and activities to the model. These changes require that the data base be modified to incorporate the new parameters. The FINERG instructions are used for modification of the data and the model to establish a new data base to construct the revised matrix.

Each modification will make the meaning of the RCDM results more difficult to interpret. As it has been recommended:

- Structural changes should be limited and should not be undertaken until the analyst has acquired some skill at working with the current model;

- Any modification should be introduced on a temporary basis until it has proved useful; and

- The original copy of the model should be maintained and used as a basis for introducing each new modification.

Since the RCDM uses FINERG software, the Community Reference System can be revised in a manner similar to the Energy Reference System of the EMP. This allows users a simple procedure for modifying the model structure. NEA staff members who are familiar with the EMP could modify the RCDM structure without much difficulty since instructions to establish new data bases for additional subsystems or activities in subsystems are clearly and simply presented in the FINERG manual.

Chapter 5

Discussion of Results

Previous Page Blank

DISCUSSION OF RESULTS

This Chapter presents the results from computer runs of the Energy Master Plan Submodels, the Household Energy Model and the Rural Community Development Model. Results of the EMP submodels are discussed by subsystem while those of the HEM and RCDM are discussed in terms of components and optimum development strategies.

A. ENERGY MASTER PLAN SUBMODELS

The Rural Energy Use Submodel

The Rural Energy Use Submodel sets up, for the first time in Thailand, a comprehensive, analytical structure linking rural energy demand, supply and conversion technologies.

Detailed investigation shows that reanalysis of existing EMP data on rural and urban transport needs improvement (see Appendix A.1 in Meta Systems Inc's report, Vol.II for a detailed discussion).

A base case (using the data base described in Chapter 3; Data base for Rural Energy Use Model) was run, and it shows that forest area depletion is taking place at a rapid pace of 7.7 per cent per annum. The rural energy use model was therefore provided with a woodfuel plantation resource option.

Three types of charcoal kilns are commonly used in Thailand: the earth mound, rice husk, and permancut kiln. Data shown in Table 3.15 indicate that there is much room for improvement of charcoal kilns. Crop residues are possible sources of energy supply.

The Energy Master Plan Submodels (Rural Energy Use, Tranportation, Electricity, Textile Industry, Paper Industry, and the Urban Household and its Tertiary Subsystem) results are presented below.

Household energy demand was examined in detail, including alternative uses of various appliances.

Sensitivity analyses revealed that some structural and some non-structural changes might have to be made. For example, two types of structural changes may be made: changes to existing links or addition and deletion of links. Changes to existing links may involve the addition of some characteristics previously omitted from a link, or deletion of a characteristic presently included. One example of this is a change in node

type from "opened" to "constrained". If a node type "00" is changed to "10" all MARKETAL statements will become binding. Addition or deletion of links is more complicated. This is required in the event of an addition or deletion of a fuel choice final demand or of a conversion device option.

Moreover, all of the data in the rural energy use model are open to modification or refinement. The Rural Energy Use Submodel was improved significantly over the original EMP.

Transportation Submodel

The Transportation Submodel was successfully built. The transportation submodel expansion allows for planning of potential energy use in transportation at a sectoral level.

Macro-level planning of energy use in the transportation subsystem can be performed easily with the newly built transportation submodel. However, various units of measurement in the transportation subsector can be greatly improved and substitutions among modes of transport need further improvement.

The test run for the base case using EMP data was successful.

Electricity Submodel

The Electricity submodel was successfully built. The Electricity submodel expansion allows for planning of potential energy use in electricity at the sectoral level.

Macro-level planning of energy use in the electricity subsystem can be performed easily with the newly built electricity submodel. However, load demand, load factors and multipliers of various types of demand can be greatly improved and should be constantly up-dated.

The test run for the base case using EMP data was successful.

Textile Industry Submodel

The textile industry submodel was successfully built and the test run for the base case using EMP data was also successful.

Paper Industry Submodel

The paper industry submodel was successfully built and the test run for the base case using EMP data was also successful.

Urban Household and its Tertiary Submodel

Due to time limitations, only the flow chart for the submodel was sucessfully developed.

B. THE RURAL ENERGY MODELS

The Rural Energy Models include the Household Energy Model and the Rural Community Development Model. The structure of these models and the results from test runs are presented here.

Household Energy Model (HEM)

The Structure of the HEM

Four types of relationships--resource constraints, production functions, output constraints, and an objective function--are included in the Household Energy Model to represent rural household characteristics. The model was divided into five components: Agriculture; Animal Husbandry; Crop Processing; Household; and Energy Conversion.

Resources are controlled directly by the household, or owned by the village, or supplied by the market outside of the village. Output can be consumed directly by the household or sold either in the village market or outside the village.

Land is classified into four types--household owned lowland, household owned upland, village pastureland and forest land. The crop package includes 14 selected combinations of crop types, lands, and seasons. Animals included in the model are bullock, cow, and pig. Meat and milk are the animal products in the model. The time dimension is divided into 6 time periods.

Energy conversion device parameters include capital costs, operating costs, labor inputs, and efficiency. Fourteen energy conversion devices are included in the model. Some of them are nonconventional/renewable energy devices such as biogas digester, biogas-fueled gas engine, gasifier-equipped diesel engine, sterling engine, and wind mill shaft power. Fuel and energy sources include collected fuels, processed energy, and commercial fuels.

Household characters are defined by size of family, amount of land controlled, quantity of animals controlled, ownership of tractor, access to grid electricity, and preference for charcoal or wood cooking.

The agricultural component includes land uses, crop production, irrigation, season, pumping energy, traction power, fertilization, and farm labor. Primary crop yields, and field and harvested residues are the products for crop packages.

Draft animals, tractors, and human labor are alternatives for traction power for land preparation. Labour requirements for cultivation are expressed in terms of person-hours per unit of land. Fertilizer requirements are specified in terms of nutrient requirements of nitrogen, phosphorous, potassium, and organic matter. Chemical, manure, field

residues and crop processing residues are the sources of fertilizer. Crops produced are consumed directly, or are processed, or sold. Field residues can be used for fertilizer, animal feed, and fuel. Pastureland and wooded areas are treated as perennials and used for cultivated crops, high-yield varieties of trees, uncultivated crops, and natural forests.

Animal husbandry, by household, includes draft labor, animal products, and manure. Crude protein and metabolizable energy are the animal nutrients required to maintain the ability to work or produce products. Dry matter requirements are expressed in terms of the maximum that animals can consume. Animals are classified into ruminant animals and non-ruminant animals.

Field residues and crop processing residues are included as available feeds. Residue allocation to animals is based on nutrient requirements and other competing demands for residue uses. Draft animals are mainly used for land preparation and their surplus hours are channeled to crop processing and transportation. Dung is used for fertilizer and feedstock for a biogas digester. Water for animals is from a public source without pumping.

Crop processing relates crop products and residues. Labor and energy are required for processing. Processed products and residues are used for food to household, fertilizer, fodder, fuel, and are also sold.

The household component includes food, cooking, lighting, water, and supply of labor Members of households are adults and children. The quantities of food, water, and cooking required are expressed in terms of unit per adult-equivalent. Wood, charcoal, and biogas are the fuels used in household cooking. Kerosene and electricity are used for lighting. Foods are supplied by direct consumption from the agricultural component, from processed crops and from animal products. The household water supply is unlimited and is exploited by small labor effort.

Household labor is allocated on a seasonal basis at a marginal return to the labor. Hired and sold labor are the possibilities. Seasonal labor demands are for 12 activities. Non-seasonal labor demands are for collection and distribution of manure and collection of residue for fertilizer and fuel.

The energy conversion component includes shaft power, auto-generated electricity, biomass fuels in engine and kilns, and charcoal and fuel wood. Nine shaft powers are considered. Labor required for shaft power is available from the household and hired. Sources of electricity are grid, hydro-electric, and self-generated. Consumptions include petroleum, biomass, fuelwood, and charcoal.

Assignment of values to Parameters

Model coefficients are determined for activities--agriculture, animal husbandry, crop processing, household, energy supply and conversions, and costs. The accuracy of the values of these parameters is dependent on the sources of information and the methods in estimating the unavailable data.

The values of parameters for agricultural activities were determined

from project survey (REP survey) statistics, and reports available from Departments under the Ministry of Agriculture and Cooperatives, the FAO report (R. d Lucia, 1983), and non-Thai sources. Some values of parameters were computed (such as amount of energy required to pump the irrigation water).

For animal husbandry, the values of parameters were determined from reports available from Thai and non-Thai sources. Some values are assumed and/or estimated.

The conversion factors for crop processing were determined from data collected from the REP and NEA surveys of small industries. Additional data were obtained from the FAO report and from non-Thai sources.

The value of parameters for household was selected to reflect conditions in Korat. The conversion efficiencies were determined from extensive testing and from the REP survey. Some values were assumed or estimated based on assumptions.

For energy supply and conversions, values of parameters were assumed and estimated from experience based on assumptions. Some calculations were done according to assumptions given.

Values of agricultural outputs were determined by comparing prices from sources. Costs of fuels and electricity were set at current prices. Cost of land was determined based on price of land in Korat. Capital costs were determined by analyzing the purchase price of the item over its useful life. Other values were based on the REP survey and available references.

The Program Functions

The matrix generating software program reads data from input files and creates a file in the format required for input by the linear programming package, MPSX.

The program is divided into sections to perform various functions. It lists the variable used and identifies its type; assigns names to the columns and rows; defines the limits to the indexes; writes the deck name record; writes the 'rows' section; reads data; creates a column section of LP problem; and contains the format statement.

To completely restructure the model and its potentials, one would need to have a complete understanding of the matrix generator and of the linear programming software package. Functional changes in the matrix generator can be achieved by changing the FORTRAN statement which specifies statements in the LP input matrix.

The parameters which can be modified are household parameters, regional parameters, technical parameters, and price or cost parameters. Techniques in changing such parameters were discussed in Chapter 4.

Making structural changes in the model is a complex procedure and involves the addition of new activities and new constraints to the model. Modification of the matrix generator is required.

The Base Case

A base case was chosen with prototypical data from Korat. The household contained 4 adults and 2 children, had 12 rai of lowland and 8 rai of upland. It had one buffalo, two cows, a pig, and a tractor. The household had access to grid electricity and irrigation water. The choices of crop packages included rice and cassava in the rainy season, vegetables and irrigated rice in dry season, and sugar and eucalyptus trees thoughout the year.

Growing of sugar cane was limited by area to provide a cash crop and animal feed for pigs. It required 18 thousand cubic meters of irrigation water to be pumped by electric motor.

It should be noted that cassava was grown due to the good prices of cassava and cassava products. The electric motor was used due to low price of grid electricity.

Sensitivity Analysis

A sensitivity run for the base case was conducted based on the changes in the availability of energy conversion technologies. Priorities in selection of energy for shaft power of the household were as follows:

- Grid electricity;
- Petroleum-fueled engine;
- Gasifier-equipped engines;
- Sterling engine;
- Animal for traction and steam power for stationary shaft power; and
- Biogas-digester and gas-engine combination.

Other sensitivity runs for the base case were also conducted based on changes in cooking fuels. Priorities in selecting the cooking fuels of the household were as follows:

- Wood;
- Charcoal; and
- Biogas.

A sensitivity run for the base case was conducted based on the changes in household assets and it was found that when a household operated without a tractor, there was only a negligible change in net income--or in any other parameter for that matter. The cows were more fully utilized and additional labor was hired to supervise the cows.

The model was run with a wealthy household with four adults, two children, 24 lowland rai, 16 upland rai, 2 bullocks, two cows, five pigs, one tractor, 20 rai of pastureland, 5 rai of forest, and irrigation water. The wealthy household had a net income approximately 75 percent higher than the base-case household.

The model was also run with a poorer household with only 6 lowland rai, 4 upland rai, 1 buffalo, 10 rai of pastureland, 5 rai of forest. Its

net income was 45 percent lower than the base case.

It was found that the base-case, rich, and poor households had significantly different levels of activities. The household with limited resources had a surplus of labor while the household with considerable resources had a serious labor deficit.

Rural Community Development Model

The Structure of the RCDM

The Rural Community Development Model is divided into five components: end-products/services goal; intermediate products/services; energy conversion; rural intermediate energy; and internal and external resources.

The end products/services goal is a set of levels of products to be produced and services to be rendered by a community. This is similar to the end-use demands in the EMP model. In each community, one could project a products/services goal at intervals, e.g. each year, every five years, etc.

The intermediate products/services are those raw materials to be converted to end-products/services through processes (if necessary). For example, paddy may either become rice if it is milled or remain only paddy if it is sold to market outside the community.

The energy conversion component allows for conversion of the end-used energy demand to demand in intermediate energy forms. The intermediate energy could be supplied from external sources or from sources within the community.

Rural intermediate energy is energy in intermediate forms required by energy conversion components to produce products and to render services for household and public uses. This includes collected fuels, processed energy, commercial energy, and animate energy.

Energy is supplied from external sources including petroleum products, transmitted electricity, lignite, etc. Energy to be supplied from sources within the community is derived from fuelwood, biogas, biomass, mini-hydro, wind, solar, etc.

Resources could be either internal or external. Most resources are limited and create the "constraints" of the linear programming methods used in this study, (such as the limitation of land, water, person-power, animals, etc).

A linear programming model is developed to maximize community income under study for given end-products/service goals and resource constraints.

To be consistent with other national planning procedures, the procedure in determining the community income in this study follows the one employed in determining National Income by the National Economic and Social Development Board (NESDB).

Rural community activities are classified into subsystems. Components are included in each subsystem whenever appropriate. The rural community subsystems are grouped as: Basic Rural Community Group (i.e. land, household, agriculture and animal); Energy Subsystem Group (i.e. energy supply and demand, and biogas/fertilizer); Small Industry Subsystem Group (i.e. rice processing, animal processing, spindling/weaving, mat weaving, pottery, handicraft, tobacco curing, rubber processing, and fermented tea processing); Community Development Subsystem Group (i.e. irrigation/water resource, fast-growing trees, village fishery, upland rice growing, soil development, rain-fed rice growing, mulberry plantation, silk worm farming, and second cropping); and services (i.e. transportation, commercial services, and government services).

The model developed has been tested with hypothetical data. The purpose of test runs is to test submodels using hypothetical data. The test runs show satisfactory results for policy implications in terms of resource allocations, economic choices of energy and technologies, etc.

Assignment of Values to Parameters

Parameters and data for the model developed were obtained from various sources such as:

- NEA 1980 Rural Energy Survey;
- Base Line Energy Survey;
- Village Energy Model;
- Energy Master Plan;
- Rural Energy Use Model, and
- Agriculture Statistics.

For the two sample case studies, data were obtained from the NEA's surveys and from the observations of the study team during its short visits to the villages. In the case that the data obtained from the survey were inadequate, data from secondary sources were used.

The Program Functions

The RCDM was developed following the concept of the EMP model. The EMP is a set of tools required for economic studies, demand analyses, and studies of supply options; it enables them to be integrated through suitable computer simulation and optimizational models, including an economic linkage model. The basic components of this set of tools are: an energy reference system (ERS); an associated energy sector data base; energy sector simulation and optimization software; a set of linkage relations used in forecasting demands for the energy sector simulation and optimization models; and a macroeconomic forecasting model.

FINERG software, used in the EMP, is used in this study. The model provides systematic formulation of the Rural Community Development Model. Using the FINERG software, NEA staff members who are already familiar with the EMP will be able to handle the newly developed RCDM without much difficulty. This is an advantage for the future modification and/or expansion of the newly developed model.

FINERG software is equipped with a conversion table to convert parameters from one dimension to another. This allows for the changing of economic parameters used in the model when the model is used for different communities having variations of value parameters.

ANCILLARY allows the FINERG software to connect flows in processes to the point where the flow has to be produced. BY-PRODUCT allows the FINERG software to connect the generated by-products to the processes where they are used.

The model has been developed within the capability of the FINERG software.

Model Simulation

Model simulation was done assuming a 3 percent real discount rate. Results are as follows:

Case of Nongwang

Case 1: Without development project. Average per-capita real income for the five year period 1985-1989 is approximately 2,914 Baht.

The main cash income is from exporting paddy, glutinous rice, cassava, and kenaf. People make cloth and mat enough for their own use in order to minimize cash expenditure.

Case 2: With development projects. It is assumed that villagers still export paddy and glutinuous paddy rather than rice and glutinuous rice.

This case shows that the average per-capita real income for five-year period 1985-1989 increases to approximately 5,000 Baht.

Optimal development strategies are found to be as follows:

-- Digging the public reservoir about 320,000 cubic metres each year in 1985 and 1986.

-- Fish Feeding in this natural reservoir--villagers committee developed to manage the public reservoir fish feeding project.

-- Handicraft and pottery introduction to villagers starting in 1985.

-- Mat and Cloth weaving remaining as is, mainly for villagers own use.

-- Postponment of cocoon-silk production and silk and textile weaving introduction. These functions should not be introduced until the market price becomes approximately 20 percent higher than the existing one.

-- Importing of some labor in the wet season. Farmers still use

the labor intensive farming method.

-- Introduction of electricity in 1987.

-- Postponement of Piped Water Project.

-- Postponement of government-subsidized Fast-growing tree project.

-- Introduction by the NEA of efficient charcoal making method.

-- Introduction of efficient cooking stove at low cost.

-- Extension of forest development. Forest development should be extended beyond 1989; the task of increasing villagers' income with minimal government subsidy is a priority.

-- Further investigation of Group or Cooperative Biogas production. Biogas production by household is not feasible. Biogas production for the community by grouping the livestock of many farmers is feasible.

Case 3: Villagers export processed rice and glutinuous rice rather than unprocessed paddy and gultinuous paddy. If rice can be exported along with Case 2, the average per-capita income for the five-year period 1985-1989 will be 6,022 Baht.

If Case 3 is implemented without Case 2 the average per-capita income for the five-year period 1985-1989 will be 3,935 Baht.

A Case Study of Huay Pui

Base Case

The basic solution obtained from optimizing the income of the Huay Pui district yields per capita income between 1986-1989 of 10,844 baht per year. The basic solution for each sub-system is discussed in detail below.

-- In the wet season, the basic run results in only 60 percent of lowland used. The expansion of land utilization is not possible due to the limited supply of water. Additional water will help add marginal yield per rai.

-- The model does not suggest additional forest area. However, government policy concerning fast-growing trees may still be beneficial, especially in terms of avoiding environmental damage.

-- With a 2 percent projected rate of population growth, labor at working age (over 14) will exceede the total labor needed for various economic activities in Huay Pui.

-- The agricultural sector is a major source of community income which contributes more than 85% to the total. The results suggest

that in the wet season, crops like tobacco, ground nuts and mung beans yield more economic returns than traditional crops like paddy (both lowland and upland) and also, yam. In the dry season, the model suggests more utilization of land in cropping garlic, onions, ground nuts, mung beans and sweet grass.

-- Animal husbandry is not proven to be a profitable activity for the community.

-- Basic food processing activities are rice milling and animal slaughtering. If farmers can sell paddy at 3,000 baht per ton and rice at 5,750 baht per ton, the rice milling is proven to have the better profit margin to the community.

-- The model suggests that in order to maximize community income, fertilizer used in the agricultural sector should be derived from animal dung in the wet season (when more animal dung can be collected) than in the dry season. However, in the dry season animal dung should be allocated to biogas production and rice residues should be used for fertilizing crops. The basic result proposes that fertilizer should not be imported.

-- Throughout 1985-89, the demand for energy used as traction power in the agricultural sector is for water buffalo. Farm mechanization such as 4-wheel and 2-wheel tractors are not attractive to farmers.

-- Fuelwood is a major source of energy used at Huay Pui. Apart from the amount (410 tons) of fuelwood utilized in tobacco curing, an additional 60 tons is used for household cooking. A very small amount of biogas is supplied to household cooking.

-- Electricity used in the household for lighting through fluorescent and incandescent light is mainly from the micro-hydro plant. There is a possibility of selling electricity generated from the micro-hydro plant to areas around Huay Pui since there is a surplus supply. The exported electricity from 1986-1989 generated from two micro-hydro plants is estimated to be approximately 1,693,200 Kwh. Diesel fuel is used extensively for transportation and shaft power. Premium gasoline is proven to be an uneconomical source of energy due to its relatively high price and the frequency of regular gasoline being sold as premium gasoline.

-- A motor cycle is an economical means of traveling, whereas the mini-bus is mostly used for transportation of agricultural and household commodities.

-- Apart from rice milling and swine slaughtering, tobacco curing is the major industrial activity at Huay Pui.

Other Cases

Several sensitivity analyses were carried out in order to answer some interesting questions about the development projects at Huay Pui.

-- After introduction of the gasifier in 1987. household income should increase from about 3,783 baht per month to 3,935 baht. An increase in income is caused by an increase in electricity generated and exported to nearby villages around Huay Pui. The gasifier will use husk and rice residues for the heating process.

-- Without micro-hydro plants, income per capita in 1985 will be reduced from 4,505 baht to 3,907 baht per year. Without a micro-hydro plant, the windmill was proven to be an attractive project for power generation.

-- Allowing water to increase by approximately 30 per cent of the total amount will increase yield per rai. Household income is raised from 1,500 baht to 1,565 baht per month. The figure somewhat underestimates the benefit of an irrigation project since the model does not deal with the possibility of expanding the cultivated area. Further exploration should proceed in this area.

-- By introducing farm mechanization in the agricultural sector, i.e. substituting machine for human traction and exporting released labor to work in the industrial sector, income per capita does not significantly change. The hub project may be beneficial to Huay Pui under the condition that the wage rate is much higher than 20 baht; and that the industrial sector labor market can absorb the released labor force from the agricultural sector without deteriorating the wage rate.

Chapter 6

Conclusions

CONCLUSIONS

A. ENERGY MASTER PLAN SUBMODELS

Rural Energy Use Model

The Rural Energy Use Model has been successfully developed as a macro-planning model for rural energy use and is particularly consistent with the whole EMP model. Test runs have also been successful.

Analysis of the Rural Energy Use Model suggests improvements in the charcoal kiln and rapid forest depletion problems. Forest plantation projects therefore need to be seriously considered for energy policy.

Other sources of energy supply are crop residues, dung, and other rural wastes.

Collection and travel time for fuelwood is a good indicator for abundance or scarcity of forest supply in most rural regions of Thailand.

Transportation Submodel

The transportation subsystem has been successfully developed as a macro-planning model for energy use in transportation and is particularly consistent with the whole EMP model. Test runs have also been successful.

Substitutions among modes of transport need further study.

There is great potential for energy conservation in this sector.

Electricity Submodel

The electricity subsystem has been successfully developed as a macro-planning model for energy conversion, distribution, and transmission in the electricity subsector, particularly with the whole EMP model. Test runs have also been successful.

Textile Submodel

The textile subsystem has been successfully developed as a macro-planning model for energy use in textile production.

There is great potential for energy conservation in this sector.

Paper industry Submodel

The paper industry subsystem has been successfully developed as a

Previous Page Blank

macro-planning model for energy use in paper production.

There is great potential for energy conservation in this sector.

Urban Household and Tertiary Submodel

Due to time limitations, this analysis was not made and, therefore, no conclusions were reached.

B. RURAL ENERGY MODELS

Household Energy Model

The basic parameters for the Household Energy Model (HEM) have been developed, based initially on a basic household profile. The HEM covers activities related to agriculture, animal hasbandry, crop processing, household, sources of energy, conversion of energy, and net income.

Data used in testing the model were obtained from several sources since an information/data bank for rural households does not exist. Many data items are based on regional data which the Study Team believes could be applied well to the household under study.

Community data and information used for testing the model were obtained from the surveys. Although the collection of data and information were not designed for the use of the HEM, the Study Team believes that they are accurate--to some extent.

A matrix generator and an MPSX were used as tools in formulating and solving linear programming problems for the rural household. Model alternative analysis as well as sensitivity analysis runs were conducted for a base case.

A Household Energy Model (HEM) has been sucessfully developed. It has been tested by using prototypical data as well as actual data obtained from selected households. The tests assure the applicability of the model which is used for household planning and/or assessment of rural household alternative activities. Major activities of rural household environments have been incorporated in the model developed.

Test runs concentrated on selected households. From the results obtained, it was found that the model developed could provide answers to questions concerning alternatives to household activities.

Analyses of resource utilization alternatives for selected households were made. It is expected that the selected rural households can be wisely developed using appropriate technologies and strategies formulated according to guidelines based on the results obtained from the HEM.

Rural Community Development Model

A Rural Community Development Model (RCDM) has been sucessfully developed. It has been tested and the tests assure the usefulness of the model which can be used for planning and/or assessment of rural community development projects. Major economic sectors in rural community environments have been incorporated in the developed model.

The RCDM data base was initially developed using a basic community profile. It has been expanded to cover activities related to renewable energy projects as well as the Government's key activities in its rural development plans.

Data used in testing the model were obtained from several sources since there is no existing information/data bank for rural communities. Many data items are based on regional data which could be applied well to the communities being tested.

Community data and information used for testing the model were provided by NEA from the surveys. Some data and information were also obtained from the investigations of the Consulting Team during a short visit to the communities. Although the collection of data and information were not specifically designed for the use of RCDM, it is believed that it is accurate-- to some extent.

FINERG software was used as a tool in formulating and solving linear programming problems for rural community development. Alternative runs were conducted for base case as well as alternative cases and sensitivity analyses.

Test runs concentrated on the 2 selected communities. From the results obtained, it was found that the model developed could provide answers to questions concerning development projects.

Suggestions on development strategies for the 2 selected communities were made. It is expected that rural communities can be wisely developed using selected appropriate technologies and strategies to be formulated based on the results provided by the RCDM.

Chapter 7
Recommendations

Previous Page Blank

RECOMMENDATIONS

A. THE ENERGY MASTER PLAN SUBMODELS

Rural Energy Use Model

Data Base Improvement. Collection, organization and catagorization of existing and incoming data are recommended; it is also necessary that these factors be included in a coherent structure designed for systematic planning and policy analysis.

The design of the data base for rural energy use is therefore needed. However, the Rural Energy Use Model does provide a useful guide to an extended data collection activity, particularly in fuelwood/charcoal demand and supply, fuel prices, device efficiencies, rural industry, and costs of new sources and technologies.

Scenario and Policy Analysis. Answers to "what...if" types of questions in model simulation, analysis and interpretation should be analysed with plausible scenario assumptions.

Shadow Prices. In-house training for NEA staff on shadow price interpretation and policy formulation would be very useful for bridging the communication gap with NESDB, Ministry of Finance and the Budget Bureau.

Demand Projection. Due to data limitations and basic research in this rural energy field, no economic elasticity concept is used. NEA should therefore continue to improve demand projection methodology.

Transportation Submodel

Transportation Master Plan. A transportation master plan should be developed, focusing particularly on spatial-dynamic theories and substitution among modes of transportation.

Expansion of Transportation Submodel. Since the transportation master plan is not available, the transportation submodel should be expanded and improved as much as possible. Possible improvements are detailed in Chapter 3.

Data Bank for Transportation Subsystem. It is recommended that a data bank should be designed for use in both the Ministry of Communication and the NEA.

Electricity Submodel

A cost minimization model of electric capacity, and a transmission

expansion model should be developed along the lines of the spatial-dynamic model.

Expansion of Electricity Subsystem. Whereas recommendations for the transportation master plan are not developed, expansion of the electricity submodel should be improved as much as possible. Possible improvements are detailed in Chapter 3.

Data Bank for the electricity subsystem. This data bank should be designed for use in engineering, financial and economic analyses.

Textile Submodel

Expansion of Textile Subsystem. Major activities in textile activites that are not included (e.g., spinning, weaving, knitting, and finishing of garments, man-made fibres, spines and nets, textile yarn, blankets, socks etc.) should be added.

Data bank for textile subsystem. This data bank should be designed for use in both the NEA and economic planning.

Paper Industry Submodel

Expansion of the Textile Subsystem. The paper industry demands that the forecast be diversified and include more types of paper such as kraft paper, paper board, print paper, writing paper, hygiene paper, etc.

Perhaps the paper industry should be linked with the sugar industry subsystem. This would provide an opportunity for study of the use of bagasse as fuel or raw material in the sugar industry.

Data Bank for paper industry subsystem. This data bank should be designed for the use of the Ministry of Industry, the NEA, and economic planners.

Urban Household and Tertiary Submodel

Due to time limitations, the analysis was not conducted and therefore no recommendations are given.

General Recommendations

Data Base Improvement. Collection, organization and catagorization of existing and incoming data are recommended; it is also necessary that these factors be included in a coherent structure designed for systematic planning and policy analysis.

Cooperation. Cooperation among various agencies is needed and responsibilities should be assigned.

Training. NEA staff should be trained to use computerized data bases and in data base design.

Scenario and Policy Analysis. Answers to "what...if" types of

questions in model simulation, analysis, and interpretation should be analysed with scenario assumptions. Consistent planning should be adhered to in each level of planning, particularly in the field of energy.

Shadow Prices. In-house training for NEA staff on shadow price interpretation and policy formulation would be useful for bridging the communication gap with NESDB, Ministry of Finance, Budget Bureau, and other energy agencies. This would ensure that planning and policy formulation among government agencies is well coordinated.

Demand projection. Elasticity and advanced quantitative analysis concepts should be introduced; due to data limitations, basic research in the energy field is inadequate.

In-house training on methodology should be given to NEA staff.

In this way, the demand subsystem of the EMP can be considerably improved as suggested, for example, in the textile and paper subsystems.

Expansion of Submodels. Expansion of submodels in the EMP in order to cover mission activities should be constantly worked on by NEA staff.

B. THE RURAL ENERGY MODELS

Household Energy Model

HEM basic activity parameters should be expanded to cover activities which are not included in the existing model structure. This will facilitate planners in conducting studies when additional activities are examined as potential projects for household development.

A data bank for the HEM parameters should be established. This task would require multidisciplinary efforts of expertise in specialized fields. Careful analysis of the data required for HEM parameters would substantially reduce efforts in data collection for the individual household under study. Data which are homogenous in the village or region should be identified and used for the household under study.

Data required for a household should be analyzed. A questionnaire should be designed for the collection of data at the household level. This should be done by avoiding the collection of data at village and regional levels which are applicable at the household level. The collected household data should be kept in the data bank.

If necessary and, if possible, additional operations using the HEM should be investigated and developed. Specifically, a systematic way to change a linear programming matrix should be generated if some parameters

are required to be changed. This will substantially reduce computer time required for an alternative run once an optimal feasible solution has been obtained. The report format of HEM should be investigated and developed to provide convenience in analyzing results.

The HEM should be used to analyze incomes of rural households in a way that will allow for different uses of resources, labor, and technologies. The model developed should be applied to household planning and/or assessment of household alternative activities, both energy and non-energy, at a household level in rural areas. This could be done by setting up priorities of household classes for the analysis.

Further analysis on the selected households in this study should be conducted. Perhaps additional households in different villages should be selected for model testing.

Analyses made by the Study Team on the testing of alternatives for the selected households should be used as the guideline in studying future households.

Rural Community Development Model

The RCDM should be used to maximize incomes of rural communities in such a way that resources, labor, and technologies will be used in an efficient manner. The model developed should be applied for the planning and/or assessment of Government projects, both energy and non-energy, at a community level in rural areas. This could be done by establishing priorities of communities.

The RCDM basic data base should be expanded to cover development activities which are not included in the existing data base. When activities are likely to be included in a potential community development project, this information should be input beforehand to help planners conduct future studies.

A data bank for the RCDM data base should be established. This task would require multidisciplinary efforts of expertise in specialized fields. Careful analysis of the data required for an RCDM data base would substantially reduce efforts in data collection for individual communities under study. Data which are homogenous should be identified and used for the community under study in the area.

Data required for a community should be analyzed. A questionnaire should be designed for the collection of data at the community level. This should be done by avoiding collecting data at the regional level which are applicable at the community level. The collected community data should be kept in the data bank.

If necessary and if possible, additional operations using FINERG should be investigated and developed. Specifically, a systematic way to change a linear programming matrix should be generated if some parameters are required to be changed. This will substantially reduce computer time required for an alternative run after an optimal feasible solution has been obtained. The report format of FINERG should be investigated and developed

to provide convenience in analyzing results.

Further analysis of the 2 selected communities in this study should be conducted. Perhaps additional communities in different regions should be selected for model testing if funds are available.

Recommendations on the development strategies for the 2 selected communities should be used as the guideline in formulating development plans for communities.

REFERENCES

Bhatia, R., "Economic Appraisal of Biogas Units in India: Framework for Social Benefit Cost Analysis," Economic and Political Weekly, August, 1977.

Cullson, A., "Feeds and Feeding," Reston Publishing, 1975.

deLucia, R., "Rural Energy Planning, A Systems Perspective," (draft) paper (FAO), Meta Systems Inc., Cambridge Massachusehs, 1983.

deLucia, R. and H. Jacoby, "Energy Planning for Developing Countries: A Study in Bangladesh," The Johns Hopkins University Press, Baltimore, Maryland,1982.

FAO, "Energy for World Agiculture," Rome, 1979.

Gohl, B."Tropical Feeds: Information Summaries and Nutritive Value," FAO, Rome, 1975.

Meta Systems, Inc., "Initial Renewable Nonconventional Energy Technology Monitoring Report," prepared for the National Energy Administration of Thailand, 1982.

Meta Systems, Inc., "Energy Master Plan Component Renewable Nonconventional" Energy Project Vol. I Rural Energy Planning
Vol. II Rural Energy Use Model
Vol. III Village Energy Model
A report prepared for the National Energy Administration of Thailand and U.S. Agency for International Development, April, 1983.

National Academy of Sciences, (NS), The Water Buffalo: New Prospects for an Under-utilized Animal, 1982.

Piriyaparn, Veera, "Agricultural Residue Utilization," paper presented at the National Workshop on Agricultural and Agro-Industrial Residue Utilization, Petchbonri, Thailand, 1982.

Raengkhum T. and P. Somboonpanya, "Development of EMP Submodel," a draft final report prepared for the National Energy Administration of Thailand and U.S. Agency for International Development, June, 1984.

Previous Page Blank

Raengkhum T., P. Somboonpanya, A. Wattanakit and P. Pornchaiwiseskul, "Rural Community Development Model," a draft final report prepared for the National Energy Administration of Thailand and U.S. Agency for International Development, July, 1984.

Robert R. Nathan Associated, Inc. et al.,"Thailand Energy Master Plan," Executive Summary

Vol. I Main Report
Vol. II Methodologies and Modelling
Vol. III Macroeconomic Analysis
Vol. IV Energy Pricing and Demand Management
Vol. V Electricity
Vol. VI Oil and Gas
Vol. VII Solid Fossil Fuels
Vol. VIII Renewable and Rural Energy
Vol. IX Institutional Consideration and Training

Reports submitted to the National Energy Administration of Thailand, The Asian Development Bank and the United Nations Development Programme, March, 1983.

Timmer, C., Peter, "Choice of Technique in Rice Milling on Java," Agricultural Development Council, 1974.

Van Buren, A., ed. "A Chinese Biogas Manual: Popularizing Technology in the Countryside," Intermediate Technology Publications Ltd., London 1979.