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FINAL ACCOMPLISHMENT REPORT
for the
RENEWABLE NONCONVENTIONAL ENERGY PROJECT

National energy Administration
Ministry of Science, Technology and Energy
and the
U.S. Agency for International Development

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1984 Bangkok, Thailand

PREFACE

The Renewable Nonconventional Energy Project was conceived by the Royal Thai Government and the United States Agency for International Development (USAID) with the aim to reduce Thailand's dependency on imported energy resources by developing and introducing alternative energy resources. The Project began in 1979 and ended in 1984.

Projects carried out under the Renewable Nonconventional Energy Project include:

Industrial Biogas
Biomass Gasification
Charcoal Improvement
Energy Master Plan Support
Micro-Hydro Project
National Energy Information Center
Pyrolysis of Rice Husks
Regional Energy Centers
Solar Thermal Processes
Solar/Wind Assessment
Stove Improvement
Village Survey
Village Woodlots
Water Lifting Technology

The Project was executed by the National Energy Administration, Ministry of Science, Technology and Energy and implemented in collaboration with various government agencies and technical institutes. Overseas procurement of equipment and arrangement of participant training was provided by the Department of Technical and Economic Cooperation (DTEC).

This report is one of 18 reports from the Renewable Nonconventional Energy Project published by the National Energy Administration/USAID,(1984) and prepared by the Office of Project Management Support. For detailed information on any of the above listed components of the Project, the reader should consult the specific component report.(See References for the list of titles.) This report gives an overview of the activities and accomplishments of the Project and is not meant to be used as a primary source document.

Chapter 1, the Introduction, presents background information on Thailand, describes the energy situation in Thailand, and presents the background, objectives, scope and significance of the Project. Chapter 2 presents summaries, conclusions and recommendations from the reports of each component listed above. Chapter 3 discusses dissemination, diffusion and adoption of new and improved energy technologies and Chapter 4 presents General Findings, Conclusions and Recommendations from the Village Survey Component. Chapters 5 and 6 contain the Conclusions and Recommendations, respectively.

Acknowledgements are extended to the United States Government through its Agency for International Development (USAID), the Department of Technical and Economic Coorporation (DTEC), and the implementing agencies, Chulalongkorn University, King Mongkut's Institute of Technology Thonburi, the Royal Forest Department, the Meteorological Department, the Thailand Institute of Technological Research and the National Energy Administration. All have played an important role in accelerating the development of renewable energy resources and in strengthening Thailand's institutional capabilities.

Accomplishments

In 1979 the Royal Thai Government and the United States Government signed the Renewable Nonconventional Energy Project agreement with the goal of decreasing imported oil, slowing deforestation and increasing rural incomes. The project had two main objectives:

1. To strengthen the capability of the Royal Thai Government in energy planning, data collection and assessment, and
2. To test renewable energy technologies for use in rural areas.

The Project has been highly successful in meeting its original objectives. The accomplishments of the Project can be highlighted as follows:

- Village energy surveys have collected valuable sociological, economic and topographical data on the rural areas of Thailand.
- Extensive meteorological data have been collected and assessed for solar and wind energy which will serve as a basis for future research and development of these renewable energy resources.
- Energy models for rural communities and household energy planning have been developed in support of the Energy Master Plan.
- The National Energy Information Center has been established with up-to-date library and computer facilities for storage, retrieval and dissemination of energy information in order to support integrated national energy planning.
- Numerous prototypes have been designed, constructed and tested in the rural areas. These include: solar dryers, solar ice-makers, solar distillaries for clean drinking water, biomass gasification systems and pyrolysis demonstration plants for utilization of rice husk.
- Several existing technologies have been improved, such as charcoal making, biomass cooking stoves, and water lifting technologies.
- Four Regional Energy Centers have been established to disseminate newly developed technologies to the rural areas.
- New concepts have been implemented into the rural villages through the Village Woodlot Project, the Micro-Hydropower Project, and other projects which either disseminated information regarding a new technology or encouraged village participation in the implementation of the technology.
- The development of indigenous expertise among villagers, government officials and implementing agencies, and the generation of new ideas from this Project will help Thailand use its energy resources more efficiently.

CONTENTS

	Page
Preface	iii
Accomplishments	v
CHAPTER 1 INTRODUCTION	
A. A Brief Geographical, Political and Historical Overview of Thailand	3
B. The Energy Situation in Thailand	5
C. Project Background and Description	9
D. Project Objectives	15
E. Scope of the Project	16
F. Significance and Impact of the Project	20
CHAPTER 2 THE COMPONENTS OF THE PROJECT	
• Village Survey	23
• Solar and Wind Energy Assessment	31
• The National Energy Information Center	35
• Support of the Energy Master Plan	43
• Regional Energy Centers	55
• Biomass Gasification	61
• Solar Thermal Processes	67
• Pyrolysis of Rice Husks	77
• Industrial Biogas	85
• Stove Improvement	89
• Improved Charcoal Production	97
• Water Lifting Technology	105
• Micro-Hydro Energy Production	111
• Village Woodlots	119

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CONTENTS (continued)

		Page
CHAPTER 3	DISSEMINATION, DIFFUSION AND ADOPTION OF RURAL ENERGY TECHNOLOGY	131
CHAPTER 4	GENERAL FINDINGS, CONCLUSIONS AND RECOMMENDATIONS FROM THE VILLAGE SURVEY COMPONENT	141
CHAPTER 5	CONCLUSIONS	
	A. Conclusions from the Project Components	147
	B. Overall Project Conclusions	163
CHAPTER 6	RECOMMENDATIONS	
	A. Continued Investigation	167
	B. Institutional Support	169
	C. Dissemination	170
Annex	Thailand Energy Situation 1982	173
References	. . . . .	181

CHAPTER 1

Introduction

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INTRODUCTION

This report summarizes the activities and accomplishments of the Renewable Nonconventional Energy Project. This Chapter presents a brief geographical, political and historical overview of Thailand; a discussion of the Energy Situation in Thailand; a Description of the Project; and the Objectives, Scope and Significance of the Project.

A. A BRIEF GEOGRAPHICAL POLITICAL AND HISTORICAL OVERVIEW OF THAILAND

Thailand is divided into four regions. To the north is a forest highland area characterized by a series of mountain ranges in the northwest, rising to more than 8,500 feet in the Inthanon Peak. The central plains are a fertile, alluvial lowland based on the silt accumulations from the Chao Phraya River, which bisects the plains and flows into the Gulf of Thailand. The most fertile section of this region is the Bangkok Delta, known as the rice basket or heartland of the country. To the northeast rises a dry upland area covering almost one-third of the country and ending at the Mekong River on the border with Laos. Peninsular Thailand, reaching to Malaysia, is a mountainous ridge.

Stretching between the fifth and 20th degrees la itude in the northern hemisphere for a distance of approximately 1,000 miles, and with elevations ranging from sea level to multiple thousands of feet in the mountainous regions, Thailand has a diversity of climate, soils, and vegetation within its borders. Moreover, its somewhat central location in Southeast Asia has given it a variety of cultural groups, particularly along its common boundaries with contiguous nations and its coastal areas; nevertheless the Thai culture overwhelmingly dominates with its language, agricultural style of life, and Buddhist religion.

Historically defined as somewhat of a buffer zone between the French and English colonies to the east and west respectively, Thailand has remained an independent nation into modern times. Until 1932, an absolute monarchy, first established in the 13th century, reigned supreme. Since then, the monarchy has been maintained and the government evolved into a highly centralized and bureaucratic one. Administration is effected at three levels: 1) central or national, 2) provincial, and 3) local.

Though commonly classified as a developing country, Thailand is somewhat unusual in that it is one of the few modern states to have escaped colonial domination. Lucian W. Pye has observed that:

> Although in Southeast Asia colonialism was the primary agent of the Western impact...(in Thailand...the Western impact) came largely under the auspices of the traditional elite.... The traditional aristocracy came to assume new roles and responsibilities as officials in the departments of government set up by advisors from numerous Western countries.
>
> The effect of the Western impact on Thailand was less drastic than in the colonial regions and large numbers of people were not violently jarred out of their traditional modes of life. The effect,rather, was to change the character of the elite; the monarchy in time lost its autocratic powers and authority gravitated into the hands of three groups of the transformed elite; the military, the bureaucrats, and the students who have returned from studying abroad.
>
> These three groups were all the products of the changes that the monarchy introduced; they were the most Westernized elements of Thai society. However, since the rest of the society had not changed as drastically, they came to occupy a somewhat autonomous position, in that they did not have strong roots in the larger society and thus relations among themselves came to dominate the politics of the country. Under these circumstances, the military became the key group...and the coup d'etat became the main device for testing changes in relative power (Pye, 1960:97-98).

Relative to many other developing countries, therefore, Thailand has had a rather peaceful history. Lacking major deposits of minerals, easily accessible stands of hardwood forests, or conditions conducive to the development of large plantations, foreign businesses have not generally established bases in Thailand. Development and/or modernization has largely been carried out under the aegis of national governmental programs derived from the interests of the military, the bureaucrats, and students educated abroad. Thus, during the past quarter century, there have been a number of concerted efforts at rural development aimed toward improvement of security. This effort has now turned toward social and economic development with a focus on energy.

NOTE: This overview was taken from "Sociological Studies on the Village Woodlot Project in Northeast Thailand", by Dr. Narong Srisawas, in "The Village Woodlot: Its Implementation in Thailand", published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

B. THE ENERGY SITUATION IN THAILAND

During the past 10 years, 1972-1982, energy use in Thailand has doubled. The rate of increase is 7% per year. Oil is the basic source of energy. In 1982, total energy production in Thailand figured in crude oil equivalents was about 7,724.943 million liters or 42% of total demand. Internal sources of energy were hydro, natural gas and lignite. Importation of energy totaled the equivalent of 11,480.888 million liters of crude oil: 2% was electricity and other sources of energy amounted to 1% of total energy imports. Total value of energy imports was 58,799.2 million baht in 1982 or 30% of the value of energy imports or 38% of the total value of exports. In 1982 the total value of energy imports was 7% less than 1981.

The total quantity of energy use in Thailand in 1982 was about 18,120.542 million crude oil equivalent liters which is an increase of 3.2% from 1981. Oil accounted for 60% of energy used. Hydroelectric power accounted for 7% of energy use, natural gas 7% and lignite 4%. Other energy sources including firewood, charcoal, sugar cane stalks and paddy husk accounted for 22% of total energy use.

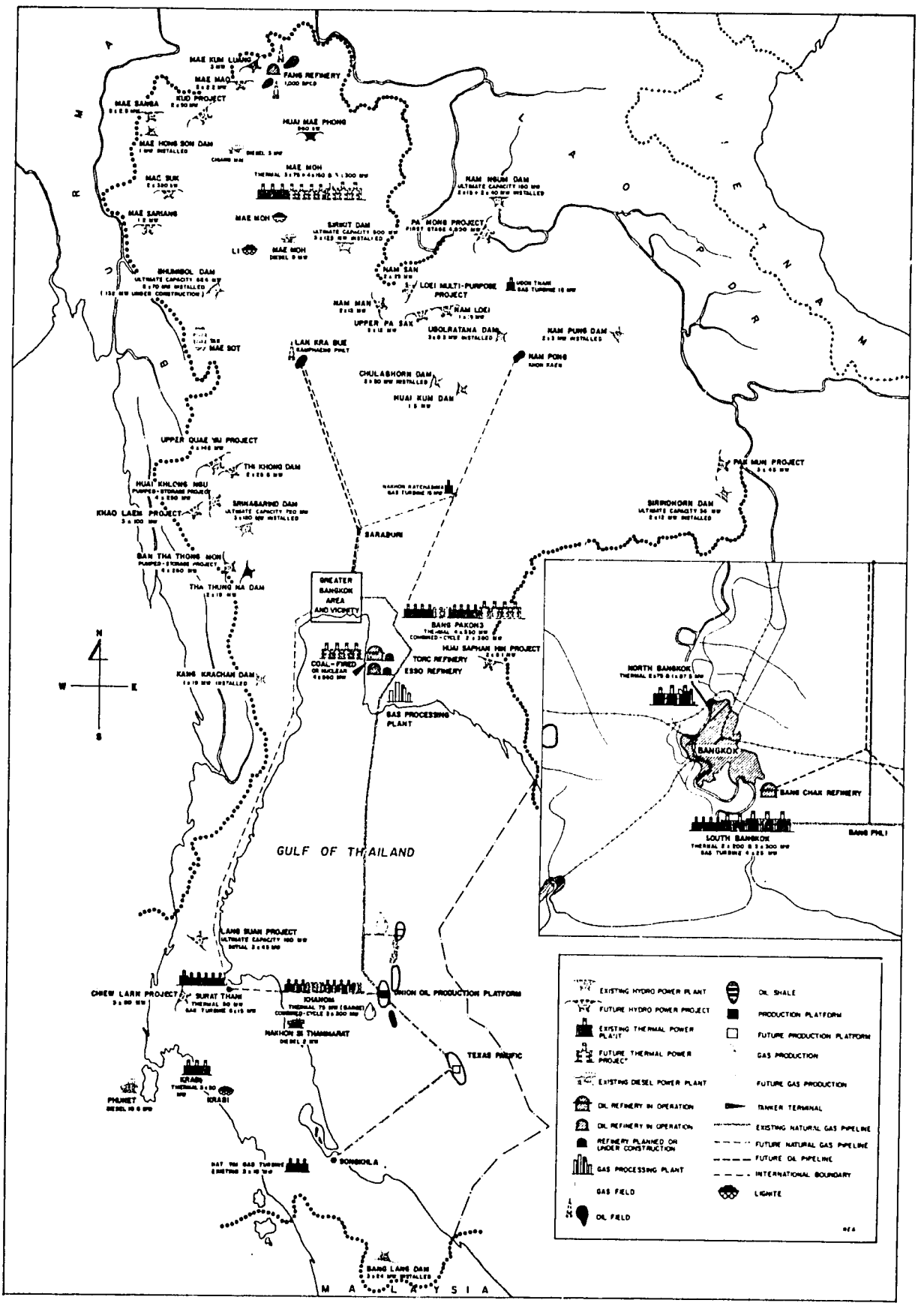
In 1982, industry consumed 29.56% of total energy use, agriculture 9.13%, communications 33.62% and commerce and other areas 27.69%. (Thailand Energy Situation, 1982. See Annex for additional details and Figures.)

The 5th Five Year Economic Development Plan has the goal of limiting the increase of total energy use to an average of 4.8% per year and to reduce oil comsumption to 46% of total energy consumption by 1986. This will be accomplished by finding internal sources of energy which can substitute for oil.

Meta Systems Inc. recommended several methods of substitution for oil imports by using renewable resources as follows:

- Partial substitution of gasoline by ethyl alcohol in motor transport.
- Mini hydroelectrical projects to replace diesel generation (although only a small effect on total national oil use) could improve rural standards of living and income.
- Small-scale electrical wind generators to replace diesel generation in areas with good wind speeds such as near the coast and rivers, on islands, plus some carefully chosen hilly areas.
- Additional small-scale windmills for water pumping to replace diesel pumps, again only in areas of adequate wind.
- Solar driers for fish, foodcrops, lumber, and other uses.
- Solar hot water heaters to replace fuel oil used by industry to raise steam and hot water for processing.
- Increasing the efficiencies of charcoal production and the end uses such as wood and charcoal stoves.

THAILAND'S ENERGY SOURCES



THAILAND ENERGY SITUATION 1982

- Use of biogas produced from wastes in rural areas to power agricultural machinery, perhaps increasing the total locally available shaft power.

- Gasifiers using biomass fuels and yielding producer gas which can be used either in industrial boilers or in engines for rural area water pumping or electric power generation.

- Pyrolysis of organic materials to produce a variety of useful products such as pyrolytic oils, charcoal, and low BTU gas.

- Photovoltaics for electric power generation.

- Solar-powered pumps.

These 12 recommendations follow rather naturally from Fig 1.2 which shows a flow chart for various renewable energy resources stemming from the sun as the initial source of the energy.

The Renewable Nonconventional Energy Project was aimed at developing and adapting the technology for a number of these recommendations.

Thailand is a country whose agricultural and forest products are its largest and most important inanimate resources. Therefore any analysis or discussion of energy resources must take this into consideration with respect to both providing and utilizing these resources.

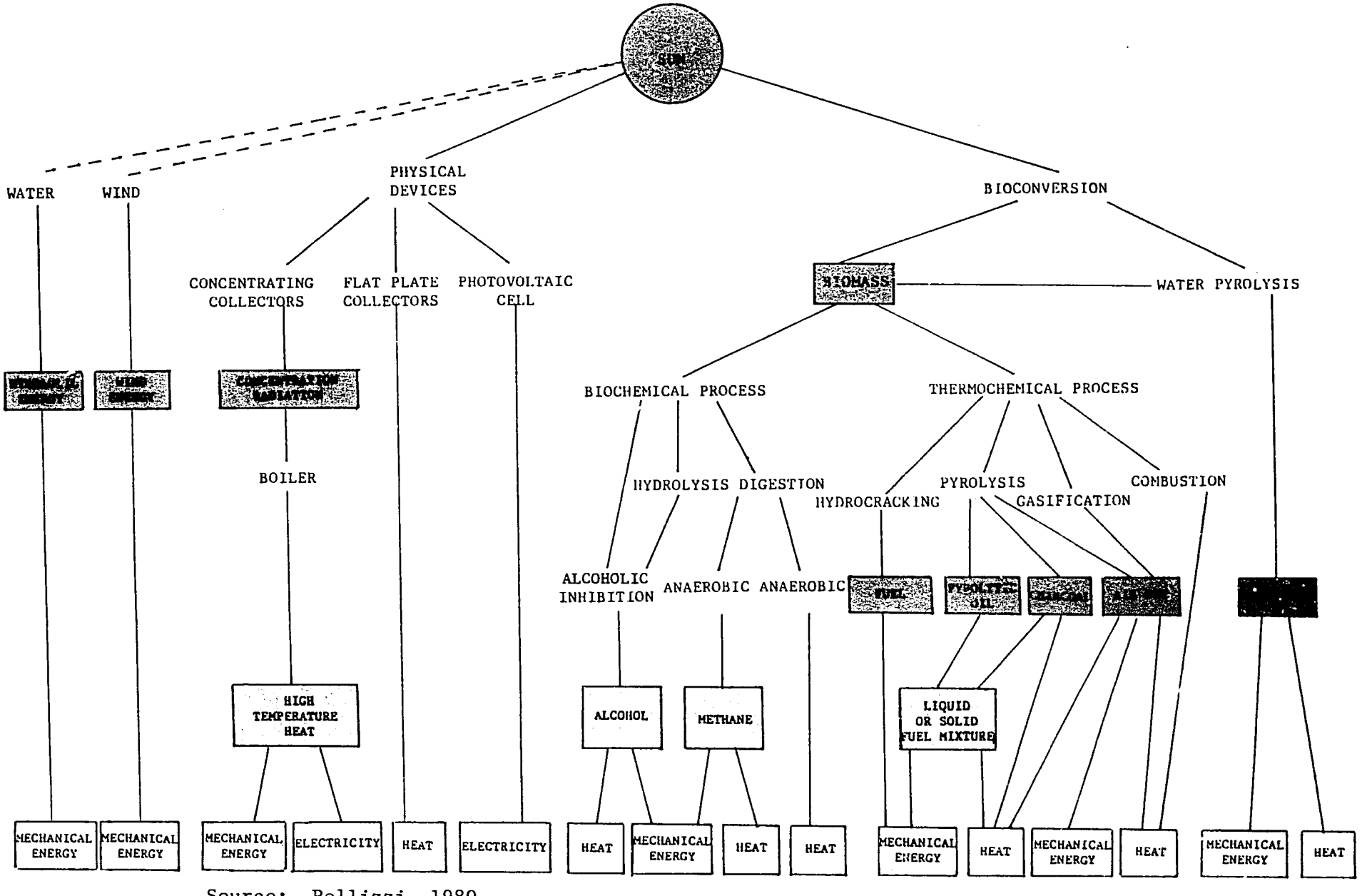
It has been estimated that just before the Second World War, the area of natural forests was approximately 60% of the total area of Thailand. The impact of fast economic development and the ever-increasing population after World War II affected the natural forests through over-exploitation, illicit cutting, mining, land settlements, construction of hydro-electric dams, and super highways. Further, the use of land for cash crop cultivation and the practice of shifting cultivation (employed by the local populace and hill tribes) left only 34% of the forest after World War II. The rate of forest degradation in Thailand is alarmingly high--approximately 333,000 hectares per year. (NEA,"The Village Woodlot: Its Implementation in Thailand",1984). Coupled with the shortage of wood fuel already experienced in the Northeast, the problem of deforestation is one of the priority areas in the development of alternative energy resources.

To summarize the energy situation for Thailand in the context of the world in general, the following conclusions can be reached.

- Most developing countries and many of the more developed countries throughout the world will face unprecedented energy crises within the next few decades with respect to both petroleim products and fuel wood.

- Thailand's energy use has doubled during the past 10 years.

Fig. 1.2 Renewable Technologies



Source: Pellizzi, 1980

- Thailand is fortunate that it has a few years to put its energy house in order, but Thailand must work with a sense of urgency if it is to be successful in accomplishing a smooth and effective transition from heavy dependence on oil and wood to renewable energy resources as replacement.

- If Thailand is to become more developed, it will be necessary for the rural areas (where 80% of the population is living) to become less and less dependent upon wood as a source of energy from the viewpoint of both convenience to the people and the rejuvenation of the forests.

- Reducing dependence on wood as a source of energy cannot be accomplished in the long run by replacing it with petroleum products. Therefore, it is essential to employ renewable sources of energy.

- Renewable energy resources originate from the sun either directly or indirectly as shown in Fig. 1. This diagram and analysis leads to the list of 12 renewable substitutes. This list applies to the energy uses for both the urban and rural parts of Thailand.

C. PROJECT BACKGROUND AND DESCRIPTION

Project Background

The Renewable Nonconventional Energy Project was planned and designed to draw upon many renewable energy substitutes, as they apply to rural development in Thailand. The energy needs for rural development (and related problems) were analysed and described in the Project Paper, USAID 1979, and the Country Development Strategy Statement (CDSS) as follows:

> As modern agricultural techniques become more widely adopted, rural Thailand will exert increasing demand for energy in the form of fertilizer, irrigation pumping, traction, crop processing, transportation to market, etc. Much of this demand will be based on petroleum as the energy source unless positive steps are taken to introduce alternatives. Substantial investment in a national rural electric system, which is a major objective of the RTG, will create a future reliance on increasingly expensive petroleum imports.
>
> The energy demand for agricultural production purposes will be additive to the needs of rural areas for cooking, lighting and other amenities. The demand for wood and charcoal for cooking in particular is already seriously affecting forest areas and could threaten the ecological system on which Thailand's rural development is based if problems of sustained usage of these renewable resources are not promptly addressed.

Through the Renewable Nonconventional Energy Project, USAID proposed to assist the RTG in reducing its dependency on imported energy sources by developing and introducing alternative energy resources. Formulating a program, however, to deal with renewable energy opportunities had to reflect the impacts and data situation at that time. They were the following:

Impacts of rural energy use patterns

- Energy responses must address alternatives in terms of immediate and tangible development benefits for rural people;
- The village poor have little access to wood fuels, residue and energy for agricultural inputs. Any program with equity as well as development objective must act to improve this access;
- There are large inefficiencies in current, rural energy use, e.g., human effort in fuel gathering, low end-use efficiency in stoves, etc., and too little energy used in agriculture and craft work. Increased productivity can be achieved by the use of more energy; and
- The environmental implications of current rural energy use are substantial--particularly soil depletion from deforestation and non-return of nutrients.

Data Situation

- There was a lack of reliable data to estimate crop and animal residues;
- There were inadequate forestry statistics for fuel wood;
- There were problems in existing consumption studies. Frequently these did not use actual measurements but relied on user estimates;
- There was a lack of information on residue-to-production relationships;
- There were few measurements of heat value, of moisture content of residues, dung, or different wood fuels, or of efficiency of end-use devices (stoves, kilns, etc.);
- There were inadequate data on availability of fuel source to the user; and
- There was insufficient information on the resource balances involving fodder, fuel, construction material, fertilizer, and their competition for residues.

This Project was therefore designed to reflect the complexities of rural energy use, to overcome some of the data difficulties, and to develop increased institutional capability for meeting the energy requirements for development.

As has been stated before, the bulk of Thai energy use is both rural and potentially from renewable energy sources. The resource depletion implications of current energy use must be compared to potential alternative applications to meet the requirement from renewable resources. Studies indicated that current rural energy use is a major cause of resource depletion, but there was also support for the technological feasibility for development of the renewable energy alternatives which were the subject of this Project.

Project Description

The Renewable Nonconventional Energy Project No. 493-0304 Grant Agreement between the Kingdom of Thailand and the United States of America commenced in August of 1979 and was to be completed on July 1, 1984. Subsequent Project Implementation Letters clarified the relationships among DTEC, NEA, the USAID and the Contractor--Meta Systems Inc.--as well as outlined responsibilities and procedures involved in planning and implementation.

The Kingdom of Thailand, the "Grantee", acted through the Department of Technical and Economic Cooperation (DTEC) and United States of America, the "Grantor", acted through the United States Agency for International Development/Thailand of the Agency for International Development (AID/W). Under this grant Thailand was to receive $3,500,000 U.S. (initially $2,500,000.00, amended to $5,000,000.00) in grant funds. The National Energy Administration (NEA) was the implementing agency and AID initially had a direct contract with Meta Systems, Inc. to provide technical assistance to the Government of Thailand.

Goals, purposes, outputs & inputs

Annex XIX of the Project Paper, July 1979 for this project stated the program goal and subgoal, the project purposes, the expected outputs, and the expected inputs (funds from various sources). These are summarized here as follows:

Program goals

- To enhance Thailand's rural development by increasing the availability of energy from other than imported conventional fossil fuels for a variety of domestic, agricultural and industrial uses of the rural population.

  - Subgoal: To reduce environmental degradation due to deforestation caused by the demand for wood for use both as fuel and in charcoal production.

Project purposes

- To ready appropriate, cost-effective, and non-environmentally destructive energy technologies for dissemination in rural areas by testing, and evaluating their technological, economic, and cultural feasibility in Thailand and by adopting them as necessary.

- To develop and test methodologies and techniques for disseminating rural energy technologies throughout Thailand.

- To develop the institutional capability and trained personnel to enable the RTG to engage in resources assessment and analysis, energy technologies monitoring and energy planning which includes consideration of rural needs.

Project outputs

- Developed awareness among policy makers and decision makers.

- Increased energy information.

- Pilot and demonstration facilities.

- Village education programs.

Project inputs

- US/AID $ 5,000,000 (grant).

- RTG $ 3,400,000 in Baht (support).

- ADB/UNDP $ 950,000 (support for EMP activity).

The Project had two complementary and reinforcing themes. First, and the longer item in its implications, was an institutional development component. This was designed to provide the basis for development and implementation of a continuing rural energy policy for Thailand. The second theme involves carrying out a series of tests and adaptations of renewable energy technologies related to rural energy needs. This rural-oriented energy technologies theme would be carried on at the same time as the work on institutional and data base development went forward. Accordingly, at the end of the project there should coincide a tested selection of rural renewable energy applications and the data and institutional base to implement them in the framework of a broader RTG energy policy.

In the Grant Agreement, it was stated that: the Project will assist the RTG work toward reducing imported energy resources, arresting environmental degradation due to deforestation, and creating increased income opportunities in rural areas. This would be carried out through:

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

The purpose was further elaborated:

- To improve the quality of life for the poor majority.
- To help develop Thai institutional capabilities to evaluate and implement best approaches to energy problems.
- To reduce imported energy resources.
- To arrest environmental degradation due to deforestation.
- To create increased income opportunities in rural areas.

Project activities

Institutional Development included plans for:

- Establishment of the National Energy Information and Documentation Center;
- Establishment of six Regional Energy Centers;
- Assessment of Renewable and Nonrenewable Resources;
- Energy Technologies Monitoring to assist RTG develop capacity to keep abreast of developments in the use of nonconventional energy resources; and
- Support of the Energy Master Plan in the area of renewable energy.

The Rural Oriented Technologies thrust of the Project was designed to accelerate the use of proven, cost-effective energy technologies in rural areas. These included:

- Biomass conversion
- Small-scale (micro) hydropower
- Solar drying
- Solar distillation
- Solar process heat
- Water lifting and
- Village woodlots.

The above activities designed to accomplish the two main tasks of the Project (institutionalization and rural technologies) were then summarized as "general component activities":

- Establishing the National Energy Information and Documentation Center and six Regional Energy Centers;
- Assessment of renewable and nonrenewable resources;
- Support for monitoring technological changes in rural energy;
- Support of the Energy Master Plan; and
- Testing and adopting energy technologies and techniques and disseminating them.

The Project was further responsible for coordinating these activities so that at the end of the Project there would be a coinciding of developed institutional capability, data and available, tested rural energy applications. This Project was seen as the framework necessary to provide the threshold conditions for addressing a whole front of Thai rural energy uses within the structure of a broader energy policy for Thailand.

D. PROJECT OBJECTIVES

In view of the foregoing analysis and discussion, the original objectives of this Project can be summarized as follows:

1. To reduce the depletion of the forests, with related ecological degradation--particularly soil erosion and reduction in soil fertility.

2. To reduce the depletion of foreign exchange caused by the import of large quantities of petroleum.

3. To reduce the dependence on oil and fuel wood in the rural areas of Thailand.

4. To replace the present heavy dependence on oil and fuel wood, at least in part, by renewable non-conventional sources of energy.

5. To adapt and test existing renewable energy technologies for use in rural Thailand.

6. To develop technologies which use fuel wood and charcoal more efficiently.

7. To improve the quality of life in rural Thailand.

8. To improve the data base and knowledge of:

   a. The forests and their use.
   b. Consumption patterns and quantities.
   c. Fuel uses and sources.
   d. Village data and profiles.

9. To develop the necessary data and institutional base to implement the renewable energy technologies which are tested and adapted for rural use in Thailand.

10. To help in developing an institutional development component as a basis for development and implementation of a continuing rural energy policy for Thailand.

E. SCOPE OF THE PROJECT

By placing the components of the Project in the two categories--Institutional Development and Rural Oriented Technologies--as in the previous section, the scope of work under each emerged as follows.

Institutional Development

- National Energy Information Center. The establishment of a new Center as a centralized source of energy information in support of RTG energy policy and planning.

- Regional Energy Centers (REC). The establishment of six RECs to support research and implementation work.

- Assessment of Renewable and Nonrenewable Resources. Organization and analysis of existing data, and collection of new data on the following subjects:

  a. Solar--assessment of available solar energy and the micro-climates to which it is related in various parts of Thailand.

  b. Biomass--making estimates of production: Variations of residue with crop species, energy content, actual availability of source/residue to users, and efficiency of fuel use.

  c. Micro-hydro-collection and analysis of micro-hydro potential.

  d. Lignite, Tar Sands, Oil Shale, Geothermal--this is an activity already under way and this project is not involved with any further assessment.

  This data was to provide material for the specific resource applications for rural oriented technologies.

- Energy Technologies Monitoring. Designed to assist the RTG in developing the capacity to keep abreast of developments--particularly with respect to the following technologies:

  - Solar thermal processes,
  - Biomass conversion,
  - Oil shale,
  - Photovoltaics, and
  - Wind power.

- Support of the EMP (Energy Master Plan). This study was sponsored by the UNDP and executed by the ADB and it initially covered the broad spectrum of energy. This project provided support for the renewable energy area, including:

  - Prefeasibility/Feasibility of Renewable Energy Alternatives,

  - Rural Energy Survey,

  - Detailed Village Resource Studies,

  - Feasibility of Village Energy Systems,

  - Staff support to provide coordination and make data available to all components as they were developed.

  - Training, and

  - Energy Conservation.

Rural Oriented Technologies

This part of the Project intended to accelerate the use of cost-effective and proven energy technologies in rural areas by testing and adapting the technologies and developing and testing techniques for disseminating them. The technologies were identified and selected according to the following criteria. The technology was selected to:

- Meet a development need of the poor,

- Have a positive environmental impact,

- Be fabricated and maintained with local materials and skills,

- Have the potential for wide-spread and large impact,

- Be affordable and theoretically controllable by individuals or by small groups of poor peasants and the landless,

- Have the flexibility to adapt to differing conditions within Thailand and to changing conditions over time, and

- Be cost-effective now or expected to be so by the end of the Project.

It was stated at the outset that the Project would not be research oriented but rather a process of selecting and adapting existing technology. (This changed somewhat during the course of the project where some technologies were not able to be implemented at the village level.)

Five rural-oriented areas of technology were identified as being of particular significance as follows:

1. Biomass Conversion. The detailed technology was to be developed to:

   - Make more efficient use of existing energy resources, and
   - Develop new energy resources such as currently wasted agricultural residues.

   These criteria were to be applied to the following specific items:

   - Improved cook stoves,
   - Biogas,
   - Improved charcoal production,
   - Pyrolysis of agricultural residues,
   - Energy conservation for small industry, and
   - Conversion systems integrated.

2. Micro Hydro Power. In both the north and south of Thailand there exist the topography and rainfall to make micro hydropower an alternative source of renewable energy. Therefore, this project was to assist up to 10 villages to develop hydro resources for productive purposes.

3. Solar Drying and Distillation. This component had two elements:

   - Solar crop dryers and solar stills, and
   - Practical industrial application of solar process heat.

4. Water Lifting Technologies. Because large parts of Thailand are underlaid with ground water that could irrigate crops, there is a need for economical pumping systems using renewable energy technologies. This project, therefore, set out to utilize wind, biogas, and solar photovoltaic energy sources for water lifting. Encouragement was to be given also to other technologies where appropriate (e.g. hydraulic ram, crop residues as heat source for steam engine, animal power, and solar thermal) but the main emphasis was to be placed upon the three technologies of wind, biogas and solar photovoltaics.

5. Village Woodlots. It is generally agreed in Thailand that the forests are being depleted very rapidly at the present time and that the situation will continue to get worse. Therefore, this component intended to utilize existing technology to:

- Provide a sustained supply of wood fuel for both woodlot owners and non-woodlot owners,
- Lessen the pressures on cutting of trees in the natural forests and poaching of trees on public land,
- Create employment opportunities and increased income for rural families,
- Develop techniques to be used as an important first step towards a country-wide scheme, and
- Stimulate interest in tree farming by demonstrating the benefits which can come from such development.

Each of the foregoing technologies meet the social/technical cost criteria set forth with the possible exception of solar photo voltaic for water lifting. For the most part, each technology was cost effective, had a positive environmental impact, met a development need of the poor, was controllable by individuals or small groups of poor peasants, and had the flexibility to respond to differing conditions in Thailand.

Project Components

When the scope of Project activities were determined, the Project was ultimately reorganized and redesigned to focus on research, development and village implementation (where feasible) in fourteen component areas. Thus, sub-projects carried out under the main project involved the Components of:

Industrial Biogas
Biomass Gasification
Charcoal Improvement
Energy Master Plan Support
Micro-Hydro Project
National Energy Information Center
Pyrolysis of Rice Husks
Regional Energy Centers
Solar Thermal Processes
Solar/Wind Assessment
Stove Improvement
Village Surveys
Water Lifting Technology
Village Woodlot

F. SIGNIFICANCE AND IMPACT OF THE PROJECT

The Overall Significance of the Project

This Project, and the approach to the energy problem which it represents, was seen as having the potential for making a significant impact in the following areas--important to both the immediate and long-range development of Thailand.

- Reduction in loss of foreign exchange due to the import of large quantities of oil.
- Reduction in the depletion of the forests and degradation of the environment.
- Replacement and reestablishment of the forests.
- Helping the rural areas of Thailand to develop and move further away from the human and animal powered society into a society which uses a balanced array of renewable energy resources--with a greatly improved standard of living.
- Help the people in the rural areas of Thailand develop a pattern of self-reliance and self-sufficiency which will carry over to other aspects of their lives to help improve their standard of living on a self-help basis.

Chapter 2

THE COMPONENTS OF THE PROJECT

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VILLAGE SURVEYS

The Survey Component was designed to assist the scientists and engineers in different energy technology components to accomplish their research and development activities. The survey was significant in that it provided a record of community characteristics before, during, and after the implementation of various renewable nonconventional energy systems and technologies.

The purpose of the Village Survey was:

- To find and present village data in order to promote energy technologies in rural areas, including a survey of alternate energy sources;

- To coordinate work with various component projects in order to choose villages or urban areas for the utilization of renewable nonconventional energy sources and equipment;

- To give basic knowledge to villages concerning these energy technologies in order to enable local communities to have a role in establishing groups or organizations to administer the project both before and after the installation of the new technology. This includes organizing village labor during the construction phase plus maintenance and operation of the technology after installation;

- To coordinate efforts between officials of various subcomponent projects and local officials in the installation of the technology in the local area; and

- To study the various problems which affect the project and to find the solutions, including an estimation of the economic and social impact to the villages or urban areas which use the renewable nonconventional energy technology.

The total surveying process for these research and development projects consisted of four phases: preparation, baseline, transition and evaluation surveys. In this report, evaluation surveys were not included because they have not yet been conducted.

The underlying concepts of the Survey Component as it was originally planned were to try to promote villagers' participation in carrying out implementation activities which hopefully would lead to self-reliance in technology operation and maintenance after implementation.

National baseline surveys were carried out in 1980. Fifty villages from ten provinces were selected for a one-month survey based on agro-ecological conditions and regional distribution. Since some subcomponent agencies needed to select additional villages to install their particular technology, the baseline survey then included an additional fifteen villages. These surveys consisted of:

- Baseline surveys in three villages concerning water pumps utilizing renewable nonconventional energy;
- Hydro-electric surveys of three areas including a total of eleven villages; and
- A survey for the Energy Master Plan Support in one village.

These additional surveys were conducted simultaneously with the operational survey because it was conducted after the installation of the renewable nonconventional energy system in the selected villages.

The baseline surveys were a collection of energy data concerning sources of energy, energy usage, energy needs and economic and social factors. This included the availability of raw materials and the moral support and physical participation of villagers which could be expected in the installation of a renewable nonconventional energy technology appropriate for each village.

There were two phases to the survey. The first phase was carried out in April 1980 in the following provinces: Petchburi, Korat, Sri Saket, Kampangphet and Lampang. The second phase was carried out in May 1980, and the provinces included were Songkhla, Chantaburi, Roi-et, Udorn Thani and Chiang Mai.

The data collected and analyzed does not claim to be a national representation. Villages were selected for in-depth study in preparation for implementation of energy technologies available in the Renewable Nonconventional Energy Project. Because of time restraints, only the baseline data from Phase I was analyzed. Certain statistical techniques were applied as a preliminary analysis and were included in this report as demonstration cases. Full analysis may be carried out at a later date.

The transition surveys considered the initial cooperational stage after the energy technology had been selected for installation. This stage was important because it required good cooperation between technicians, analysts, villagers and local officials. Initially, the

analysts estimated the willingness of the community to cooperate. They conducted public relations efforts designed to familiarize the community with the new technology that was to be installed. When the community was ready to accept the new energy system, the next step established supervisory agencies and prepared a labor force. The establishment of supervisory agencies was a critical step for the analysts because these agencies could determine the success or failure of the project since after the officials departed, the agencies remained to administer the project.

Transition surveys included in this report consist of data from:

- Woodlot surveys in four provinces (Sri Saket, Roi-et, Maha Sarakharm and Yasothorn);
- Community Biogas surveys in two villages in Sri Saket and Roi-et Provinces;
- Micro-hydro surveys in eleven villages in Chiang Mai Province; and
- Water Lifting surveys in three villages in Sakhon Nakorn, Nakhon Ratchasima, and Yala Provinces.

The evaluation survey was set up to determine the impact of the new technologies on the social and economic situation of the villages. It was to include the level of acceptance by the local community of the installed renewable energy technology. Because of time restraints, the evaluation survey has not yet been conducted in depth. This paper only considered problems which arose and surveyed people's overall opinions of the project.

The results of the surveys may be said to be good learning experiences. Conditions were diversified and needed to be treated case by case. In almost all cases, community settings were different, indicating that baseline and transition surveys are essential if implementation is to be carried out to meet the needs of the community. The introduction of a new project should be welcomed by everyone concerned before implementation; therefore, attention should be given to information gathered from the survey, especially when there is an indication of differences in opinions or practices at the village level. Lessons learned and reported in this volume should be treated as guidelines to assist in future projects.

Conclusions

- The implementation of an alternative energy technology requires not only specific information of the locality but also a well formulated technique designed to actively involve the local villagers in the formation, implementation, operation and maintenance of the designed technology.

- For implementation of a project to be successful, one must not walk into the community blindly. The baseline survey, when carried out prior to implementation, should serve as a background and guideline for future activities.

- Baseline surveys need to be conducted on every component. Transition surveys carried out prior to implementation will lead to successful implementation if social problems identified by the survey are solved.

- Evaluation surveys were not conducted for this study due to time limitations. They are good measures of social and economic changes in the community, they pinpoint problems of acceptance and provide technology diffusion information.

- The results claimed in the analyses by the Village Survey Component can only be claimed as guidelines for use in the data analysis of other energy surveys.

- The surveys conducted by this component have provided important baseline information regarding the rural areas of Thailand that will have many uses in the future. Be cautioned that these surveys cannot be considered as statistically representative of Thailand as a whole, but they are still extremely valuable within themselves as they represent provinces with specific energy resources.

- The analysis of the structure of variables by factor analysis was not applicable for this set of data. We can view this analysis as an exercise in factor analysis application.

- These results will be useful in choosing the statistical methods which should be used in future surveys. Thus, in turn, means that scaling and quantification of variables can be built into the questionnaire and will not need to be a separate function during coding or analysis.

- As far as the analyses of the data are concerned, certain primary conclusions were obtained from the analyses run (factor analysis, multiple regression, discriminant analysis and Pearson's correlation matrix);

  - The decision to go further/nearer for fuel collection depended on the size of the household, how many household members were responsible for fuel collection and how many rais of land they had access to;

  - Neither the use of firewood nor charcoal were indicated by household economic status. Traditional habits and familiarity determined the energy practice in each household;

  - The amount of fuel used depended mainly on the needs of the household as identified by household size;

  - Most people used fuel in traditional ways. Most did not apply or even think about methods of fuel conservation, methods of cooking or how to use fuel beneficially; and

  - Kerosene consumption showed a relationship to household income and lighting equipment.

- The energy components cannot always consider themselves as isolated units. The success or failure of a component might well rely on the implementation of other projects, such as a new road to carry produce to market, produce that was grown using an improved nonconventional energy technology. Each element relies on each other.

- The value of the social scientist has been played down in many instances. However, in several cases, project failures or project marginal successes were due to social rather than technical failures.

Recommendations

- Special efforts should be made to equip the personnel (especially the technicians) involved in the projects with a good understanding of village life, concentrating on the community's ways of thinking, its behavior and, if possible, important village relationships. Project personnel will, in short, be public relations representatives of the Royal Thai Government and of their energy component, a responsibility which is viewed with as much importance as their technical expertise.

- Research and Development is important, but without a solid implementation program the results will not pass the "practical application" test. Therefore, attention should be given to the implementation stage with close supervision by the technical specialists.

- Technical specialists need to give more attention to the implementation stage of the project so that technical/construction difficulties do not cause a failure of project acceptance by the local community.

- It is recommended that in the future, the Survey Component should proceed with every phase of the surveys (preliminary, baseline, transitional and evaluation) for every technical component in the project.

- The evaluation surveys should be conducted over a long enough period of time to ensure an accurate assessment of each project.

- Training on participatory implementation techniques should be offered and required for technicians working on rural energy development.

- The training curriculum for implementation of nonconventional energy technology should consist of:

  - General knowledge on different energy technologies;

  - General knowledge on participatory techniques; and

  - General knowledge on implementation stages or project cycle.

- If training cannot be offered, energy implementation personnel should be made aware of the need to involve local people in every stage of implementation, especially the initial stages.

- Energy personnel should have a positive attitude toward the local people and should be able to work with the local people with an understanding of how to involve the villagers in the formation, implementation, operation and maintenance of the designed technology.

- In Survey Data Analysis, if the volume of data is large and must be divided into two phases, it is necessary to design the two phases to be the same. Alternation of the questionnaire and alternation of the data frame will only make the computer analysis more complicated and more time consuming, especially if there is any lag time between data coding and data analysis.

- Data should be prepared for statistical analysis before coding. Preparations such as scaling, arranging all answers to have the same direction of scaling, and quantification of variables requiring it, should be made prior to actual computer analysis.

- The statistical tools that are to be applied in the analysis should be identified before formulating the questionnaire. In this way, only the necessary variables will be included and redundancy can be avoided.

- Redundant and unnecessary variables should be minimized. It was found in this analysis that many of the variables were not applicable to Thailand.

- The surveys should definitely be continued.

NOTE: For the report in its entirety see, "Rural Village Surveys in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Charcoal-making Survey to Test the Efficiency of the Charcoal Stove.

Students Conducting an Interview with a Family Headman in Nakon Ratchasima Province.

SOLAR/WIND ASSESSMENT

The objective of the Solar and Wind Resources Assessment Component was to specify how the solar and wind energy potential of Thailand could be reliably determined and subsequently monitored. The Meteorological Department was the agency responsible for this component. The project started in 1981 and will be completed in 1984. After the project has been completed, its activities will be continued by the Meteorological Department on a routine basis.

The assessment of solar and wind energy for Thailand consisted of:

- Establishing a Center for Solar Radiation and Wind Calibration; and
- Evaluation of data.

In order to do the assessment, additional solar radiation and wind measurements were required. For this reason, 6 solar radiation monitoring stations and 10 wind monitoring stations were set up. At these stations, observed solar radiation and wind are transformed into electrical signals and fed into dataloggers for real-time data processing. The processed data were then automatically recorded on magnetic tape cassettes for further analysis.

Evaluation of data was divided into existing data and new data. Evaluation of existing data by King Mongkut's Institute of Technology, Thonburi Campus; and evaluation of new data (1983) by Dr. R.H.B. Exell from the Asian Institute of Technology show that, except at some coastal sites, solar energy has higher value than wind energy. A detailed analysis of existing and new data has been published separately from this report as "Solar and Wind Energy Potential Assessment of Thailand", (Suwantrakul et al., 1984) and "Solar and Wind Energy Data of Thailand 1983", (Exell and Sukawat, 1984).

Besides setting up new measurement, collection and data evaluation processes, the project calibrated the existing solar radiation and wind instruments of many agencies. These efforts form a solid base for further data analysis in the future.

Previous Page Blank

Conclusions

- The activities of the solar/wind assessment component were centered at the Meteorological Research Sub-Division, Studies and Research Division, Meteorological Department.

- The Center for Solar Radiation and Wind Calibration was established at the Calibration Sub-Division, Instrumental Division, Bang Na Meteorological Office.

- Additional measurements are done at 6 stations for solar radiation, and 10 stations for wind. All additional measurements are automatically recorded by dataloggers.

- There is a problem with continuity of data recorded by the datalogger due to instrument malfunction.

- Calibration of solar and wind instruments faced problems because of time limitations, human resources and spare instruments.

- National standard solar radiation instruments were calibrated at WMO Regional Centers in Australia.

- Maintenance of solar instruments, wind instruments, and a datalogger is hindered by the problem of unavailable spare parts within Thailand.

- Analysis of existing data by KMIT and new data by Dr. Exell of AIT was completed and published as separate technical reports.

- In-country training was mostly completed as it was planned, but overseas training was cancelled due to the delays at DTEC.

- Foreign and local consultants proved very useful.

Recommendations

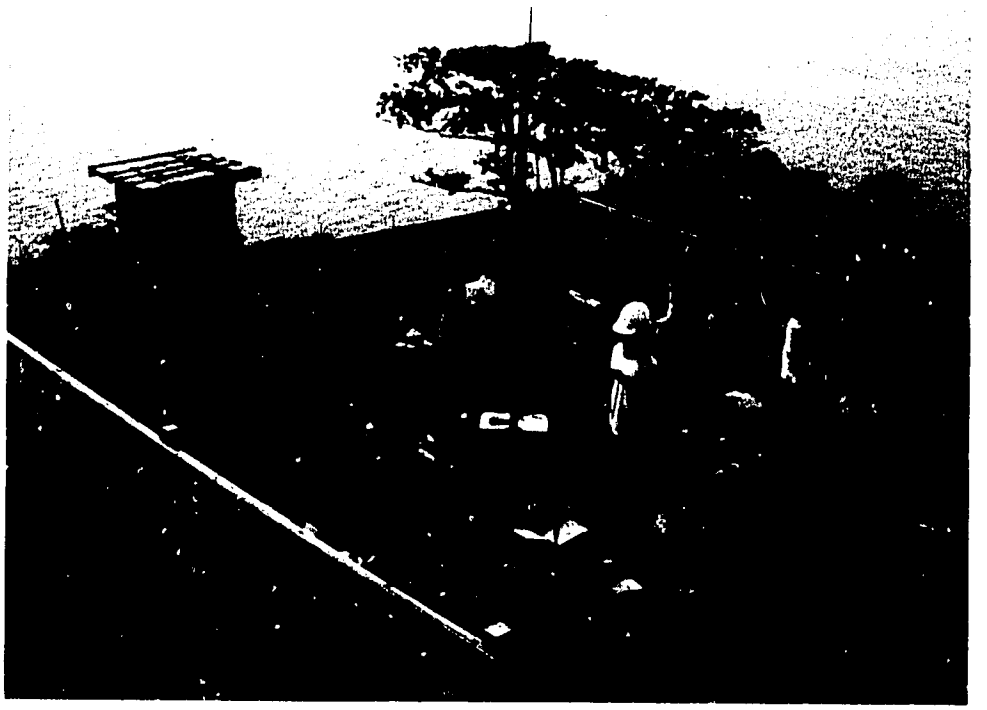
- Additional measurements of solar radiation and wind should be taken (both in space and time) to yield more representative data for further research.

- The datalogger used in automatic data recording should be modified for more durability. Spare parts should be sufficiently supplied to ensure continuity of recorded data.

- Qualified researchers and operators should be assigned to carry on project activities, and should be trained to be able to do the job without the assistance of a consultant.

NOTE: For the report in its entirety see, "Solar and Wind Energy Resource Assessment for Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Wind monitoring system used in the analysis of wind data for EGAT's wind-generated electricity project located at Khuan Phrom Thiap, Phuket.



Installation of Black and White Pyranometer at the Hydrological Observation Station, Ban La Mai, Ko Samui, Surat Thani.

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NATIONAL ENERGY INFORMATION CENTER

The National Energy Information Center (NEIC) was established by a Cabinet decision on November 21, 1978, at the National Energy Administration, Bangkok, Thailand. It is a prototype energy information center for both the public and private sectors in Thailand and was established with the following goals:

1. To serve as a comprehensive energy data center which collects, organizes, analyzes and disseminates energy information, particularly in renewable nonconventional sources in order to support integrated national energy planning.

2. To serve as a referral center for energy bibliographic and numerical data in Thailand, whereby information about past and ongoing research in all aspects of energy are available to users.

3. To provide this information regularly to users, in and out of the National Energy Administration (NEA), through a computer system and its varie forms of output, and through publications using selective dissemination of information processes based on user profiles.

4. To build a basic collection of books, serials, conference papers, microfiches and magnetic tapes and the like, on the local and international energy situation, which is organized according to recognized international standards.

The NEIC achieved these goals through the implementation of a basic plan that can be summarized as follows:

- Revision of the sources of energy information through interviews, correspondence with agencies, visits to energy centers, as well as acquiring and utilizing basic reference tools.

- Basic reorganization of existing library facilities to create a modern information center.

- Renovation of the NEA library to provide adequate facilities and attractive surroundings for users.

- Installation of a computer system and development and establishment of data processing activities and building data bases.

- Training of local staff on information systems.

- Issuance of publications to users in English and Thai.

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The NEIC can now disseminate information on the development of renewable and indigenous energy sources as well as create an awareness of the importance of energy resources, their consumption and environmental considerations. By automating information, The NEIC is playing a leading role in collecting and disseminating information for use in the energy planning process on the national scale.

Conclusions

Organization of the NEIC

- The NEIC was established by a Cabinet decision at the NEA in 1978. It serves as an energy information center in which all types of energy data, documents and reports are collected. This data was analyzed and used to formulate the Energy Master Plan. The NEIC is a prototype energy information center for both public and private sectors in Thailand. In addition, it serves as the energy information referral center for information exchanges among other agencies.

- In 1982 the NEA reorganized its divisions and the NEIC became a section of the Energy Policy and Planning Division. At present the NEIC includes the NEIC Project, the NEA library and the System Analysis section.

- The NEIC established an up-to-date energy library organized according to international standards, and which was referred to by users regularly.

- The computer system was installed in June 1984, therefore, data processing activities will be forthcoming.

- The NEIC library was renovated and equipped with new equipment and furniture.

Staff and Training

- The NEIC civil servants were provided formal training on information systems in Bangkok and on Hewlett/Packard hardware in Singapore.

- The NEIC organized a software (MINISIS) training program with technical cooperation from the International Development and Research Center (IDRC) during June 24-July 13, 1984, at NEA for its staff and other interested institutions.

- The NEIC provided ongoing on-the-job training during 1982-1984 for all the staff.

- The NEIC is short of personnel because of frequent staff turnover.

Development of Data Activities--Bibliographic and Numerical

- A bibliographic data base in energy was established by NEIC, in an external computer system, comprising approximately 1,200 records.

- At the same time, 940 records were prepared for input, and 2,300 were selected for bibliographic documentation.

- After the installation of the mini-computer system in June 1984, the bibliographic data base using the MINISIS software was established.

- The NEIC documented procedures for bibliographic data and for numeric data processing.

- The NEIC is processing renewable energy data, NEA administrative records, meteorological and hydrological data.

- The NEIC developed a thesaurus of energy terms for the data base.

Development of Library Activities

- The NEIC inventoried all the library collection and discarded peripheral material.

- The NEIC inventoried all the library procedures, flow-charted them and published them in a Library Procedures Manual.

- The NEIC established an up-to-date energy library in two languages--English and Thai.

Services and Publications

- The NEIC offers some user services based on the library collection and some data base services from the bibliographic data base.

- Regular services and on-line searches will be offered by the NEIC computer system.

- Information services are provided for NEA Divisions from the numerical data base.

- The NEIC documented guidelines for readers on how to use the library.

- The NEIC issued a newsletter, bibliographies, and manuals, in Thai and in English. Some of these publications were produced on NEA premises, while others were printed by professional agencies.

- The NEIC printed at least 200 copies of each publication for distribution inside and outside of Thailand.

- The NEIC developed a mailing list of people and centers inside and outside Thailand who receive its publications.

- The NEIC surveyed energy centers in Thailand and ASEAN for the purpose of printing a directory of potential users.

- The NEIC published a brochure (in English and Thai) announcing its services and publications.

Recommendations

Organization of the NEIC

- The NEIC should be unified in a single unit so that the user can easily locate all the information. The interrelation between the library and the computer center should be more clearly identified and the services offered to the users should be made more distinct.

- The library, though renovated, remains small. It may be able to accommodate growth in the collection, but not for more than two years. More spacious premises (of at least double the present ones -- 64 m^2--128m^2) will be needed in the future.

- The computer center is also small. Any contemplated expansion of the system must consider larger premises, particularly for accommodating the staff.

- In the future, NEIC needs stronger support in terms of budget and manpower; otherwise it will not have sufficient resources to handle the functions and services as planned.

Staff and training

- The staff are to be commended on the support that they gave to the NEIC Project. A recommendation is made that permanent status be provided in order to try to eliminate the frequent turnover of the staff.

• Managerial capabilities should be developed to coordinate the data base as a whole. Through the USAID Project, there was no time to implement the training of a data base manager. The NEIC has requested assistance from the United Nations Development Programme (UNDP) to provide this training for 1985-1986. For this reason, NEIC needs to follow-up this matter closely with UNDP, which in turn has exhibited willingness to provide support.

• Additional training for the NEIC staff should be provided to develop the numerical data base -- particularly in how to use data through the Energy Master Plan model. Such possibilities will need to be considered with the experts of IDRC and UNDP at a later date.

• The library does not have sufficient staff. It is recommended that two more qualified civil servants be employed to assist in building the bibliographic data base and in the production of publications.

• Translation from English into Thai is a daily occurrence at NEIC, particularly since energy information of any international significance is published in English; therefore, all NEIC staff need to be better versed in the English language.

Development of Data Activities--Bibliographic and Numerical

• The NEIC plan in 1982 had envisaged the preparation of 4-5,000 records in the bibliographic data base. That number was prepared but only 1,200 were input in EBIS at ESCAP. It is recommended that the tape be brought from ESCAP, integrated at NEIC and all records be input. This should be an ongoing process.

• As for the numerical data base, an expert in this field would be helpful. Although the NEIC officials have received initial training, they will still need expert guidance to utilize the new system to its maximum capabilities, and to see how it can be used to fulfill the needs of NEA, particularly in the issuance and publication of data. A manual outlining these procedures should be written. In the future, it is recommended that both the numeric and bibliographic data bases receive equal attention as far as data base management is concerned.

• With the installation of the new computer system at NEIC, a leading role for the NEIC should be encouraged and developed--that of a referral center for energy information in Thailand. A regional network for renewable energy information is being established in Manila, Philippines with UNESCO support and the Ministry of Science, Technology and Energy is the focal point for this network in Thailand. Thus, if NEIC is given the needed support and funds it could assume the role of handling energy information for Thailand.

• The NEIC should also widen its sources of information by subscribing to international energy information sources and data bases. Although these will require a large outlay of funds, the information they provide, particularly the statistical type, is worth the expenditure.

Development of Library Activities

Additional staff should be employed in the library to assist the librarian in preparation of bibliographic data, producing publications and managing the library and reference services.

- The NEIC should continue to assume an active role in providing users with information regularly through the distribution of bibliographies, surveys and other publications.

Services and Publications

The NEIC must begin to assume a more aggressive role in disseminating information. In order to assume this role the following should be considered.

- The NEIC should avoid becoming archival.

- The NEIC should search and determine the NEA information needs by regularly meeting with the NEA Divisions.

- The NEIC should be the only referral source for energy information in Thailand.

- The NEIC must maintain an up-to-date energy library with an emphasis on energy statistics.

- The NEIC must continously publicize these services in order to attract more users.

- The NEIC needs to continue the publications issued through Project assistance. It is recommended that additional personnel be assigned to this unit and an effort be made to have these publications professionally printed.

- The NEIC should continue the *NEIC NEWS* as a quarterly publication. Numerous positive responses were received concerning this newsletter. At least two staff members should be assigned to its production. An effort needs to be made to compare it with other NEA publications to determine its value and to avoid duplication. More original articles or features could be included along with surveys of Thai expertise in renewable energy sources.

- The library should continue issuing bibliographies from the data base on a regular basis. This should be done often, depending on how frequently the data base is updated.

- The NEIC should maintain contact with the ASEAN energy centers that were identified through the Directory, and should search for more centers to issue a supplement.

NOTE: For the report in its entirety see, "The Establishment of the National Energy Information Center in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

The NEIC Library after renovation.

NEIC staff using Hewlett Packard terminals.

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ENERGY MASTER PLAN SUPPORT

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".

Three major studies were undertaken:

- Meta System Inc.: 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).

All systems, including energy systems, can be broken down into components or elements--called subsystems. Accordingly, 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. 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.

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 analyses on structural and nonstructural changes to answers of "what...if" kinds of questions were simulated. 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 (Sectoral Energy Planning Models: Supporting Studies of Thailand's Energy Master Plan, published by the National Energy Administration, under the Renewable Nonconventional Energy Project (#493-03C4),Bangkok, Thailand, 1984.)

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 consitent with the whole EMP model. Test runs have also been seccessful.

- Substitutions among modes of trasport 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 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 household 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. Models alternative analysis as well as sensitivity analysis runs were conducted for a base case.

- A Household Energy Model (HEM) has been successfully 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 resources utilization alternatives for selected households were made. It is expected that the selected rural household 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 successfully 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 Consutling 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 Consutling 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 energy 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.

- 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.

- 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 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 bagasses 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 base 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 additonal activities are examined as potential projects for household development.

- A data bank for the HEM parameters should be established. This bank 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.

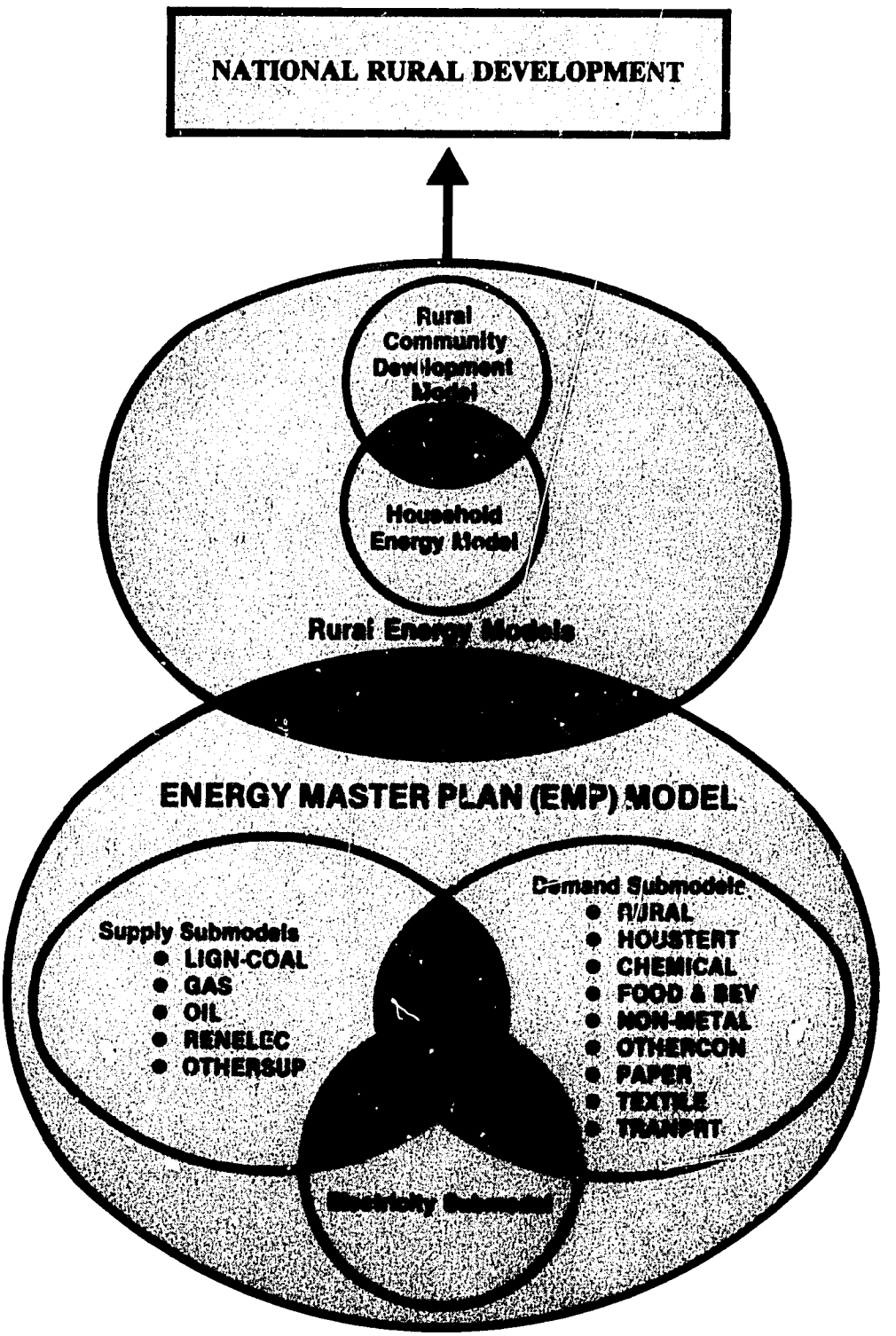
- If necessary and if possible, additional operations using FINERG should be investigated and developed. Specifically, a systematic way to change a linear programming matrix should be generated if some parameters are required for an alternative run after an optimal feasible solution has been obtained. 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 communites 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 guidelines in formulating development plans for communities.

NOTE: For the report in its entirety see, "Sectoral Energy Planning Models: Supporting Studies of Thailand's Energy Master Plan, Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project # 493-0304, Bangkok, Thailand, 1984.

Relationships Among Models and Submodels of the Energy Master Plan



REGIONAL ENERGY CENTERS

The Regional Energy Centers Component focused on providing rural communities in Thailand with the established and developed energy technologies capable of meeting basic energy needs in areas such as cooking and household lighting. In addition, energy which could help raise the standard of living and add more income to families, such as water pumping for irrigation and electricity production for rural industries, needed to be disseminated into rural areas of Thailand. This effort required demonstrations, assistance, selection of the relevant rural technology, installation, training and maintenance. The program strove to spread these technologies throughout rural areas as an assistance to the Royal Thai Government's rural development program.

Regional Energy Centers (RECs), to be effective, need the following items: one workshop, one warehouse, one training hall, an electrical system and a water supply. In terms of equipment, each center requires workshop tools, field tools, laboratory and monitoring instruments and dissemination or visual aid training equipment. For demonstrations, prototypes of energy technologies are needed for solar energy, wind energy and biomass energy. In terms of vehicles, one 2-ton truck, two 1-ton trucks, two motorcycles and two bicycles are required. The staff requires engineers or scientists, technicians of various levels and areas of specialty, guards, a labor force and drivers.

REC operations initially faced obstacles in areas such as methods, procedures, laws and communication which slowed the project down, but eventually the problems were solved and objectives were met on time. Funds for the implementation of the RECs came from the Royal Thai Government budget and from USAID assistance. The United States contributed US $458,620 (or 10,545,260 Baht) for the construction of buildings and for the purchase of tools, equipment and instruments. Total fund usage was 8,888,853 Baht. A total of 1,656,407 Baht was saved by purchasing articles at the lowest available price.

Operational and personnel responsibilities began even before the RECs were completely established. These areas included baseline village surveys, coordination, promotion and public relations. In 1984, the Maha Sarakharm REC and the Phitsanulok REC were fully established and were operating as planned. The Ratchaburi and Nakhon Sithammarat RECs still face a severe shortage of full-time officials. This problem was circumvented with the use of NEA staff consultants who are available to travel to various centers as needed to solve difficulties on a contingency basis.

Previous Page Blank

Conclusions

The operational processes of the REC from its conception until the end of the 1984 project can be summarized as follows:

- Four Regional Energy Centers (RECs) have been installed in Maha Sarakharm, Phitsanulok, Ratchaburi and Nakhon Sithammarat Provinces.

Each center consists of an administrative office, chief's house, assistant chief's house, rowhouse (for four families), workshop, warehouse and training hall.

- Public utilities supply the water, electrical systems and roads.

Tools and equipment have been procured and include workshop tools, field tools, laboratory and monitoring equipment, communications equipment, training and visual aid equipment.

- Vehicles have been purchased and consist of a 2-ton truck, two 1-ton trucks (pick-ups), two motorcycles and two bicycles.

- Sixteen staff members are working at the Maha Sarakharm and Phitsanulok RECs. There are five staff members at the Nakhon Sithammarat REC and four staff members at the Ratchaburi REC.

- Energy technologies (prototypes) to be used for demonstrations of and as examples of available energy technologies have been installed. These consist of solar hot water and solar distillation techniques, solar dryers, windmills, photovoltaic cells, biogas digesters, biomass gasifiers, efficient cooking stoves and efficient charcoal production kilns.

- 100 rai of *Eucalyptus camaldulensis* and oil seed trees have been planted at the centers and 70,000 plants of *Eucalyptus camaldulensis* were introduced to village plantations as a renewable village fuel source.

- 368 demonstrations and promotional activities on the utilization of energy technologies were conducted: 92 on biogas plants, 200 on efficient cooking stoves and 76 on charcoal production kilns.

- Village surveys were conducted in 56 villages within the center's areas of responsibility. Data were collected on the basic and increased income of people in each village, energy needs, indigenous resources and its potential.

- There were 225 villagers, local government officials, village leaders, public school teachers, etc. trained at the RECs on the subjects of biogas digesters, windmills, efficient charcoal production kilns, efficient cooking stoves, the construction/fabrication, uses and maintenance of each technology, etc. Also, additional training was given to those people who had already been trained but needed more assistance and who were interested in installing

the equipment for their personal usage. The results from twenty-one training sessions were highly satisfactory and the RECs were requested to continue training. Those who had been trained at the centers became important energy promoters who helped to disseminate energy technologies to rural areas of the country.

- Training results were monitored and assessed for their effectiveness and in order to solve obstacles and problems.

- The energy demonstration and promotional programs resulted in the continued dissemination of energy technologies. These were the family biogas plants, community biogas plants for electricity generating, photovoltaic cells for water pumping, windmills for water pumping, charcoal production kilns, etc.

- There were 1,575 visitors to the RECs.

- 4,550 printed materials on energy technology were distributed.

- REC activities were advertised 62 times.

- The RECs conducted 12 joint exhibitions with other government agencies for public relations and the dissemination of REC activities.

- 34 coordination sessions and lectures were conducted with other energy components and government agencies interested in installing comparable or related technologies.

- An analysis of the RECs in the closing stages of the project showed that despite unanticipated obstacles during the establishment stages, the RECs achieved their objectives and obtained the results listed in the conclusions.

Recommendations

- Provisions need to be made to provide full staffs at all centers. An understaffed REC results in a limitation of operational potential.

- The RECs have field tested numerous training/information dissemination/ public relations methods and activities. Those various methods which have proven successful in advertising and promoting the RECs and the various technologies should be made a part of the promotional activity plans for newly established RECs.

- The monitored results of twenty-one training sessions showed that they were highly successful. The REC should definately continue this activity as those personnel who received the training have become important energy promoters who are helping to disseminate the information on these renewable energy technologies throughout the rural areas of Thailand.

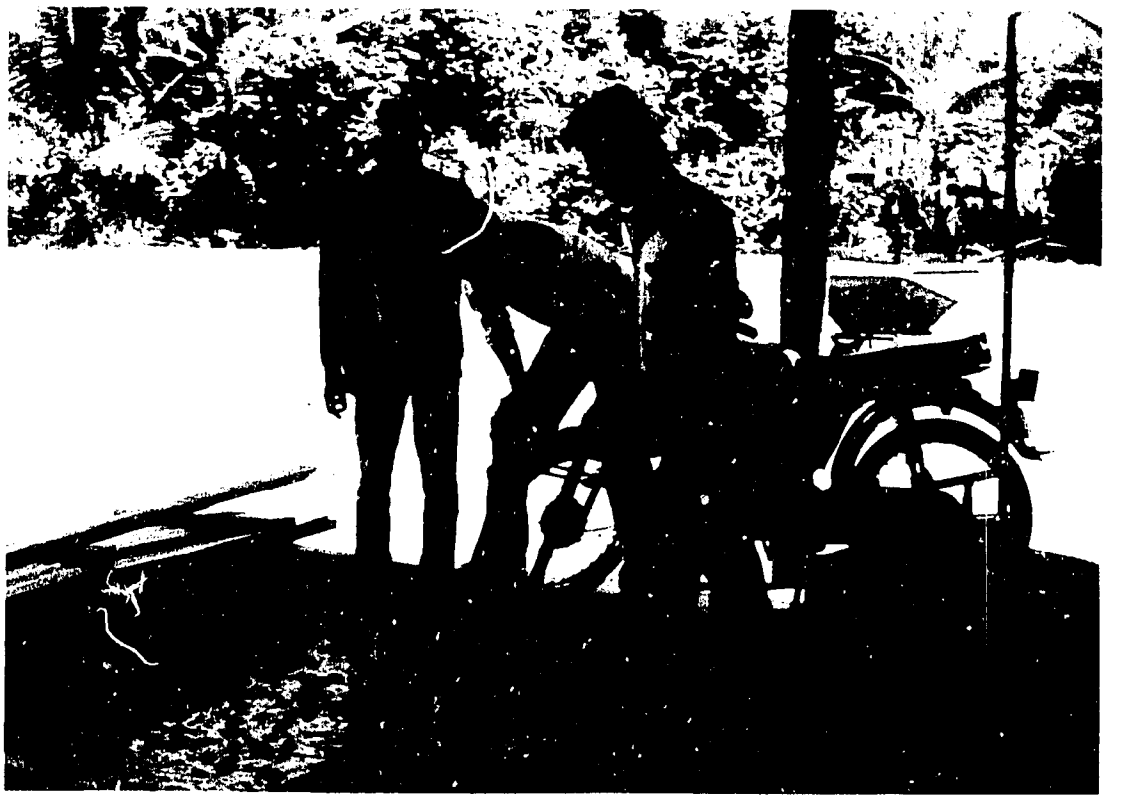
- Training must be continued because it is the only method to disseminate energy technologies in rural areas of Thailand with highly efficient results.

- Coordination sessions with other government offices and energy components should continue so that there are no overlapping efforts and so that related activities and projects can begin simultaneously.

- An analysis of problems which were encountered in the early phases of the project will help in the establishment of future RECs and will encourage efficiency and mission accomplishment.

- Additional Regional Energy Centers should be set up to cover a wider area of Thailand.

NOTE: For the report in its entirety see, "The Establishment of Regional Energy Centers for Rural Development in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.



Promotion of family biogas digester at a REC.

REC's training facilities

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BIOMASS GASIFICATION

The general objective of the Biomass Gasification Component of the Renewable Non-conventional Energy Project was to develop a number of gasification systems and based on testing and/or implementation programs, recommend a set of proposals for the development and/or dissemination of Biomass Gasification technology in Thailand.

Under the project twelve gasification units were planned starting from a series of microgasifiers producing five hundred watts of electricity to gasifiers producing twenty-five kilowatts of electricity, and pilot scale fluidized bed systems of sizes below one third of a million Btu per hour. At the completion of the project these twelve gasification units were at various levels of construction and testing. One unit had gone through a full implementation program in a rural site.

The main conclusions of the study indicate a reasonable amount of confidence in the development of small charcoal gasifiers and confidence in the prospect of disseminating these units; that wood gasifiers need be technically optimized before implementation; that fixed bed crop residue gasification show prospects of becoming a future gasifier raw material; and that fluidized bed gasifiers have been shown to be able to gasify rice husk.

The recommendations based on the study state that small charcoal gasifiers be disseminated; that additional development towards full operational reliability be done on wood gasifiers and that future wood gasification programs include wood production programs; that fixed bed crop residue gasification be undertaken at the research and development level, that fluidized bed crop residue gasification be implemented on an economic scale, using both local and foreign expertise; that importance be attached to fixed bed direct fire gasifiers for drying applications; and finally that gasification development, implementation, and dissemination work be coordinated by a center with various R & D groups supporting this center as resource persons.

Conclusions

The following conclusions may be presented based on the work undertaken by the Biomass Gasification Component in the development of several gasifier systems.

Charcoal Gasifiers

- Charcoal gasifiers producing half a kilowatt of electricity have been developed and implemented successfully. Gasifiers producing in the range of seven horsepower have also been developed and tested successfully but not yet implemented.

Crop Residue Gasifiers

- Research into novel fixed bed downdraft gasifiers using corn cob pieces has shown the possibility of developing a simple geometry gasifier that may eventually be able to gasify a variety of low ash content and high ash content shredded crop residues.

Wood Gasifiers

- Choke plate downdraft wood gasifiers developed and tested in this project indicate that such a gasifier design has almost reached the point of being able to produce a comparatively tar-free gas. Furthermore such a gas can be cooled and cleaned in a packed bed water scrubber. However, both reactors and scrubber need to be further optimized in the laboratory.

Fluidized Bed Gasifiers

- The fluidized bed gasifiers of up to about 20 kw, designed, built and operated in this project, indicate that rice husk can be gasified, although data from both pilot units built indicate that the units have not been fully optimized. The complexity of operating such systems means that a unit of less than half a megawatt,for example, would probably be uneconomical and the development of such a large fluidized bed gasifier would require hardware inputs from abroad and use of both foreign and local expertise.

Recommendations

The recommendations that the Biomass Gasification Component wishes to make from the project results and the experience gained during the project may be presented as follows:

The Dissemination of Small Charcoal Gasifiers

- Based firstly on the development of microgasifier systems from sizes ranging from 500 Watts of electricity to systems producing in the neighborhood of 7 hp of shaftwork, and with some limited implementation experience, and based secondly on the appraisal of low negative impact on wood resource depletion in certain areas of rural Thailand, it is the recommendation of the component leader that a dissemination program be undertaken.

- One dissemination strategy that may be undertaken at low cost is the training of villagers in the construction of charcoal gasifiers either in Bangkok or at the rural energy centers.

The Development of Wood Gasifiers

The various phases of wood gasifier development should include the following items:

- Laboratory research and development of a wood gasifier system to obtain optimized systems should be encouraged including long term testing and implementation.

- Since wood gasifiers are generally designed for applications which generate shaft power up to several hundred horsepower (also utilizing up to several hundred kilograms of wood chips per hour thus creating an environmental problem), it is very much necessary to tie in a wood production and preparation system with each wood gasifier implementation and dissemination program.

- In order to minimize still further tar production from a wood gasifier, it is very interesting to study the use of semi- carbonized wood as a wood gasifier fuel. Likewise, to increase general conversion efficiency of charcoal gasifiers, it is very interesting to study the use of semi-carbonized wood as a charcoal gasifier fuel.

The Development of Fixed Bed Crop Residue Gasification

- Due to the non-use of Thailand's agricultural crop residues, it is important to promote biomass conversion technology that would enable farmers to gain additional income from such wastes and at the same time convert this biomass into useful energy. The gasification of crop residues in fixed bed gasifiers offers some prospects of successful development and research and development in that direction should be promoted.

The Development of Fixed Bed Direct Fire Gasifier Systems

- One of the items of development not specified in the Biomass Gasification Component was the development of a wood or crop residue fixed bed, downdraft gasifier for direct fire applications. Such a concept not yet engineered in Thailand would seem to have wide use in small scale wood drying, agricultural crop drying, tobacco leaves drying, etc. The technology would appear to be less difficult then producing an engine grade quality gas as we would have less worries about tars which do burn in direct fire burners. Such a development direction should be looked at and worked on for subsequent work.

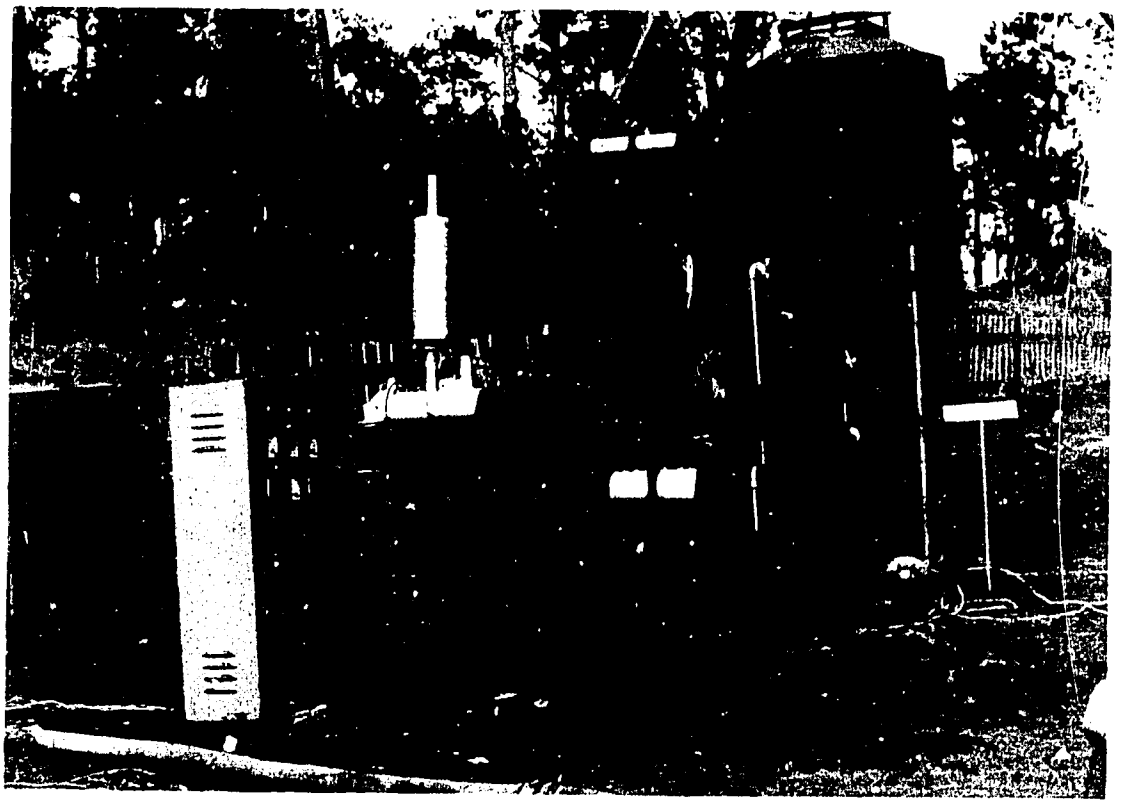
The Development of Crop Residues Fluidized Bed Gasifiers

- Based on the results of this project it can be said that the concept of rice husk gasification is feasible. As a recommendation from this project the next step should be to build a small but economical scale gasifier (it is proposed that not less than half a megawatt thermal be considered) and to use under-utilized crop residues in a rural factory to test the economic viability of the system.

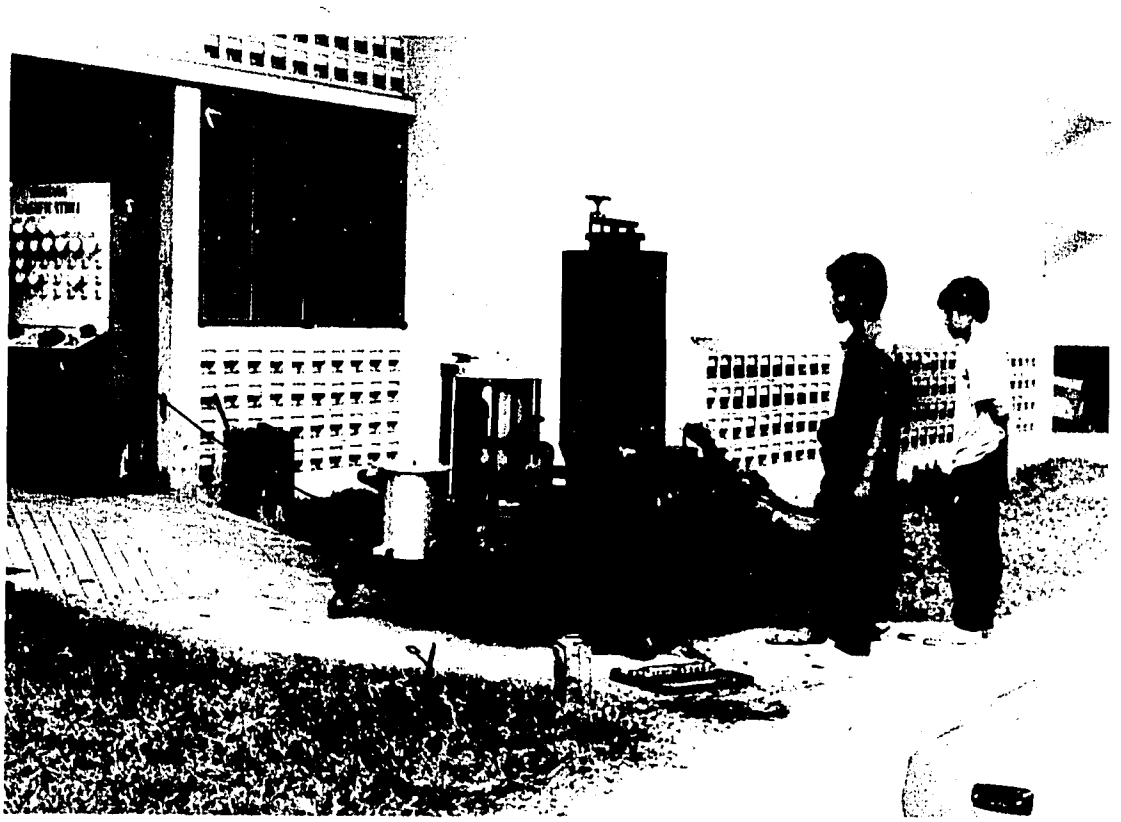
Proposal for a Gasification Technology Development Center

- Based on the Biomass Gasification Component's experience acquired during the project, on the contacts with Biomass Gasification development teams in Thailand and on perceived future prospects of biomass gasification dissemination in Thailand, one recommendation proposed here is the creation of a central gasifier development facility. This center would coordinate research and development work through subcontracts to existing R & D teams and be solely responsible for overseeing planning and implementation programs. Failure to centralize activities relating to biomass gasification will result in duplication of efforts and much slower than optimal development of the technology.

NOTE: For the report in its entirety see, "Biomass Gasification in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.



A Downdraft Charcoal Gasifier producing 2 KWe



Downdraft Wood/Corn Cob Gasifier Producing 25 KWe

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SOLAR THERMAL PROCESSES

The objective of the Solar Thermal Processes component is to develop solar thermal equipment suitable for different applications in rural and urban areas of Thailand. Three types of solar thermal processes namely, solar distillation, solar refrigeration and solar drying have been investigated.

Solar Distillation

As clean water is needed for domestic and other specific uses in many rural and urban areas, three types of solar stills are being developed for different applications. The first design of modular basin-type solar still with a horizontal absorbing area of 1 sq m, consisted of a double-wall basin made of fiber-reinforced plastic. After long-term tests on sixteen solar stills at different locations, it was found that distilled water obtained from the stills was too acidic and yielded a strong smell of resin. A short-term test on an improved design having aluminium as the inner basin and charcoal chips as the absorbing materials yielded good-quality distilled water. Twenty units of improved stills were fabricated and put into different field operations. Their assessment should be available at the end of the year.

For urban applications, a vertical-surface solar still with 2.4 sq m absorbing area is being designed after some preliminary investigations on two models with glass and plastic covers. An improved design of a low-cost still with a concrete basin of 6 sq m absorbing area is being carried out. It is expected that long-term tests for the last two types of the stills will be completed at the end of the year.

Solar Refrigeration

A test model of a solar ice-maker with a capacity of 15 kg of ice per day was designed, constructed and tested. An ammonia-water absorption refrigeration system was selected. Several test runs confirmed that the test model could produce 15 kg of ice per day. Based upon the test model, a second ice-maker was designed with emphasis on ease of operation. The unit is currently under construction and it is expected that by November 1984, the unit will be completely tested and ready for field operation. It is expected that solar heat for the system will be provided by advanced solar thermal collectors already developed or by an existing solar pond of 52 sq m which is currently under investigation.

Solar Drying

Research and development on three types of solar drying were carried out--natural convection cabinet drying, forced convection hut drying and solar tobacco curing.

a) Natural convection cabinet drying

An efficient solar air heater has been developed and incorporated into a free convection cabinet dryer for agricultural products. Five identical dryers were constructed and tested at five selected sites in rural areas. Products tested were bananas, salted fish, salted beef and sweet coconut chips. For salted beef and coconut chips, the drying times in the cabinet dryer were reduced by about 20%, and the drying process was satisfactory. However in the drying of banana and salted fish, the drying times were not significantly shortened.

All users nevertheless agreed that the cabinet dryers provided hygienic products and they were interested in using the dryers providing that they were affordable. Applications of the dryers to different products would require experience and careful operation. In some cases, an addition of a chimney to improve air circulation may help by distributing heat in the dryer when a high drying temperature is not required.

b) Forced convection hut drying

With regard to research and development on a forced convection solar hut for grain drying, the solar collector was modified from the roof of a barn using corrugated galvanized iron sheets as an absorber. Air flowed between the absorber and the styrofoam insulation which was placed under the absorber with a spacing of 20 mm. No transparent cover was used in order to simplify the construction of the collector. From test runs it was found that the maximum thermal efficiency was 30 percent at the air flow rate of 0.0181 kg/sm^2. Tests were also carried out on the solar collector with dull black paint absorber. The maximum thermal efficiency of 34 percent was found. It was concluded that the unpainted solar collector is preferred. By developing and using a mathematical model, comparison between the experimental results and the simulated ones shows that they are both in agreement.

About one ton of paddy was dried in a vertical fixed-bed dryer by solar energy and ambient air in two different manners. Both employed the technique of continuous ventilation. The moisture content of paddy was reduced from 22 percent to 16 percent db in about one day. It is preferred that drying start in the morning and terminate the following morning because the moisture gradient was significantly reduced by ventilation of ambient air at night before the end of drying.

c) Solar tobacco curing

In the solar-assisted tobacco curing project, a solar air heater of 38.5 sq m absorbing area, a rock-bed storage of 1.8 x 1.8 x 2 cu m and a tobacco curing barn were designed and constructed. Preliminary test results on 820 kg of fresh tobacco leaves were obtained by using LPG or solar heat. Substantial savings of fuel by using solar energy were obtained. Two additional batches of tobacco leaves were cured by solar energy with LPG as the auxiliary heat source. Further investigations are being conducted on various modes of operation using solar heat and auxiliary heat sources.

Conclusions

Solar Distillation

Basin-type Solar Still with One Acrylic Plastic Cover

- The acrylic plastic cover is less prone to be broken by accidents than the glass cover. Resistance to degradation by solar radiation of the plastic cover however, may be less than that of the glass cover.

- Charcoal chips are preferable as the absorbing material to the black butyl rubber sheet since the former perform equally well, are cheaper and locally produced, and they can also absorb any undesirable smell in raw water.

- All three improvement methods on the vertical back wall of the still increased the daily distillation rate by about 13%. Therefore, the addition of the black cotton cloth is preferable since it is the cheapest method.

Modular Basin-type Solar Stills with Fiber-reinforced-plastic

- After long term tests, distilled water obtained from sixteen modular basin-type solar stills with double-walled fiber-reinforced-plastic bodies was too acidic with pH values of about 4-4.5.

- When the fiber-reinforced-plastic inner basins were replaced by aluminium ones and charcoal chips were employed as the absorbing meterial, the quality of distilled water improved considerably with pH values of about 6.5. The water is now suitable for drinking.

Silar Still Models with Vertical and Flat Absorbing Plates

- The solar still model with the vertical glass covers gave higher distillation rates than those with the plastic covers by about 10%.

- At a high global radiation above 20 MJ/m^2 d, the still models with the vertical absorbers facing east-west yielded higher distillation rates than those with the absorbers facing north-south. At a radiation below 20 MJ/m^2 d, the reverse results occurred.

- Distances between the vertical absorbers and covers were much wider than the optimum gap obtained from the mass transfer consideration alone.

Solar Refrigeration

- The successful test run of the model unit brought about the confidence to try several modifications of the model, and experimental studies are being carried out continuously. The results obtained will be reported at the end of each specific study. Meanwhile, the prototype unit is being built, and is expected to be completed in December 1984.

- Within a few years, the research team should be able to develop further the technological process of ice-making by solar energy in the rural village. Technically, ice has been made; however, the economic and social aspects will have to be evaluated after further technological improvements.

- The research program has served to create additional research activities within KMITT, and has resulted in an extensive training program for individuals involved in solar refrigeration research.

Natural Convection Cabinet Drying

- All users agreed that solar-dried products are cleaner and more hygienic than sun-dried products. The dryer protects the products from intrusion of animals, and prevents spoilage due to wind and rain.

- The success of the application of the dryer to various products is dependent upon each product, individual techniques of the drying process, and those characteristics of dried products that are accepted by particular communities since the drying characteristics of products vary from one to another.

- The villagers who are involved in small-scale drying are not interested in adopting the solar-drying technique. Those who dry a medium amount of produce show interest, provided that the quality of the products are better or, at the least, the same as sun-dried products. They also require that besides, the dryer be cheap and efficient. These results imply that the natural convection cabinet dryer would be inappropriate for industrial scale drying.

- If the only purpose of drying is to reduce the moisture of the product, and its color and texture are not significant, the solar-dryer developed for this study will serve the purpose. However, with certain products such as bananas where color, and softness affect the quality and price of the product, careful operation and experience are required to use this dryer effectively.

- The following conclusions concerning dryer design characteristics can be made.

  - Wire mesh trays become rusty and cause cuts on the product surface.
  - Ventilation of humid air in the dryer was low and affected the quality of the products.
  - Temperature of the top tray was too high.

Forced Convection Hut Drying

- The maximum efficiency of the unpainted and dull black painted solar collectors are 31% and 34%, respectively. The unpainted solar collector may be a more attractive choice than the dull black painted one if low initial investment is preferred.

- The mathematical model developed can predict the thermal efficiency of the solar collector accurately at low inlet air temperatures. However, the theoretical efficiency is overestimated at high inlet air temperatures.

- From the results of the drying tests, it seems that a drying technique like the first drying test (where drying begins in the morning and terminates the following morning, and the ventilation of ambient air is done at night before the end of drying) is preferred to the technique followed in the second test (where drying begins in the evening and terminates the following evening) because there is an advantage of a smaller moisture gradient of paddy in the dryer.

- The economic analysis indicates that the solar hut dryer used for drying alone is economical when the cultivation area is about 25 rais and two crops per year is practiced. If the solar hut dryer is also used as a paddy storage, the minimum cultivation area is reduced to 17 rais.

Solar Tobacco Curing

- The use of solar heating resulted in energy savings of up to 20% (conservative estimate) in this study with LPG as the main fuel.

- The authors believe that solar-assisted tobacco curing is technically viable, and that energy savings in the order of 30-40% over LPG are attainable, given more experience, more typical weather conditions, and better fresh leaves.

- Whether a thermal storage would be useful in a solar-assisted tobacco curing process is still uncertain, due to limited data obtained in this study.

- Tobacco curing is a complicated process involving many factors. Any energy-usage comparison between any two curing systems should be made on at least two identical curing barns, with similar fresh leaves and curing procedures, under the same weather conditions.

- From an economic aspect, investment required for the solar heating unit is barely justifiable by the resulting savings in conventional energy consumption, at current prices. To make a solar heating system more attractive economically, either fuel prices have to increase, or the barn has to be utilized more, for example for drying of other crops during the off-season for tobacco.

Recommendations

Solar Distillation

Basin-type Solar Still with One Acrylic Plastic Cover

- Long-term outdoor tests should be conducted on the still to determine the life-times of the acrylic plastic cover and of the cotton cloth on the vertical back wall.

- An economic and social assessment of the still should be carried out before it is promoted for field applications.

Modular Basin-type Solar Stills with Fiber-reinforced Plastic Bodies

- After long-term field tests, economic and social evaluation of the stills with aluminium inner basins should be attempted by means of large-scale demonstration units.

- A more suitable resin should be selected as the material for the inner basin in order that distilled water does not become too acidic. Advantages of the true fiber-reinforced plastic basing can then be achieved.

Solar Stills Models with Vertical & Flat Absorbers

- Taking the effects of mass transfer and global radiation into account, true optimum gaps between the vertical absorbing plates and covers should be determined for east-west and north-south orientations.

- Transient phenomena inside the vertical solar still should be studied so that the sill performance can be accurately predicted.

- Long-term outdoor tests should be conducted on large-vertical-surface solar stills with acrylic covers facing north-south and east-west directions so that their technical and economic performance can be assessed.

Mass Transfer Theory

- The prediction of the distillation rate by means of the convective mass transfer theory in this work still requires the values of the wet and dry bulb and interface temperatures inside the solar still. The theory should be further developed so that the measurement of these temperatures will not be needed for the prediction.

Natural Convection Cabinet Drying

- Wire-mesh trays can become rusty and cause marks and cuts on product surfaces. Trays made from bamboo or nylon nets, which are cheaper, should replace wire-mesh trays.

- It was observed that ventilation of humid air in the dryer was low. This affected the quality of the products. Thus, a larger outlet port opening is suggested. The work in progress at King Mongkut's Institute of Technology, Thonburi (Wongsiri, 1984) reports that when a ventilation fan ($\sim$ 40 W) was placed at the top-back door of the dryer, the heat distribution in the dryer was improved and this improve. the product quality.

- The temperature of the top tray was too high. The users suggested that the outlet-port be enlarged or the transparent roof (cover) changed to an opaque sheet.

- The results of the study showed that the most interest was generated by medium-scale users. Thus, further studies in developing a more efficient dryer should concentrate on this group.

- Procedures for ensuring careful operation for the dryer to produce attractive products should be established where appearance is a critical aspect of saleability.

Forced Convection Hut Drying

- The low-cost solar air heater developed in this study is suitable for drying agricultural products on the farm because it is cheap and easily constructed. However, high efficiency solar air heaters may be of more interest to small scale rural industries. The efficiency of the low-cost solar air heater can be significantly improved by adding a transparent cover over the absorber.

- Mathematical simulation of solar paddy drying is also important because it can be used to aid in the design of similar solar drying systems.

- It was observed during the test that loading paddy in and out of the dryer was hard work even for farmers. Therefore, the solar hut dryer should be modified so that it requires a minimal amount of labor.

- Introduction of the solar hut dryer may cause a change in the chain of rice production. Thus the farmers may not accept it. In addition, the poverty of the farmers is also an important consideration. It would be valuable to do a socio-economic study.

Solar Tobacco Curing

- Further experiments should be conducted, preferably with two identical barns.

- In future experiments, attempts should be made to isolate the effects of solar-assisted heating, rockbed thermal storage, other conventional fuels (firewood and lignite), different types of fresh leaves, and different curing procedures, under otherwise controlled conditions.

- Serious considerations should be given to test-run the tobacco curing barn as a multiple-crop dryer during the tobacco off-season, to increase its utilization and to make investment in a solar heating system more economically feasible.

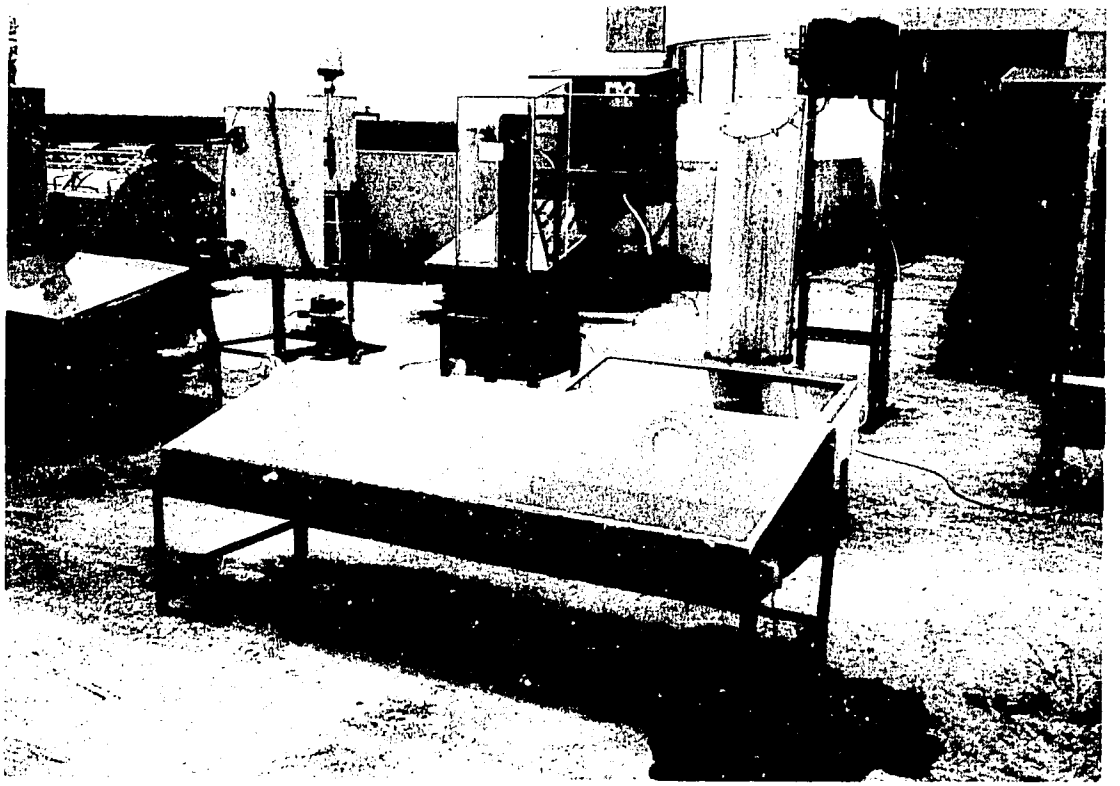
NOTE: For details see the following reports:

"Solar Thermal Processes in Thailand: Studies on Solar Distillation and Solar Refrigeration",

"Solar Thermal Processes in Thailand: A Study on Solar-Assested Curing of Tobacco Leaves",

"Solar Thermal Processes in Thailand: A Study on Forced Convection Hut Drying",

"Solar Thermal Processes in Thailand: A Study on Natural Convection Cabinet Drying", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.



Modular Basin and Vertical Surface Solar Stills

Solar-Assisted Tobacco Curing System

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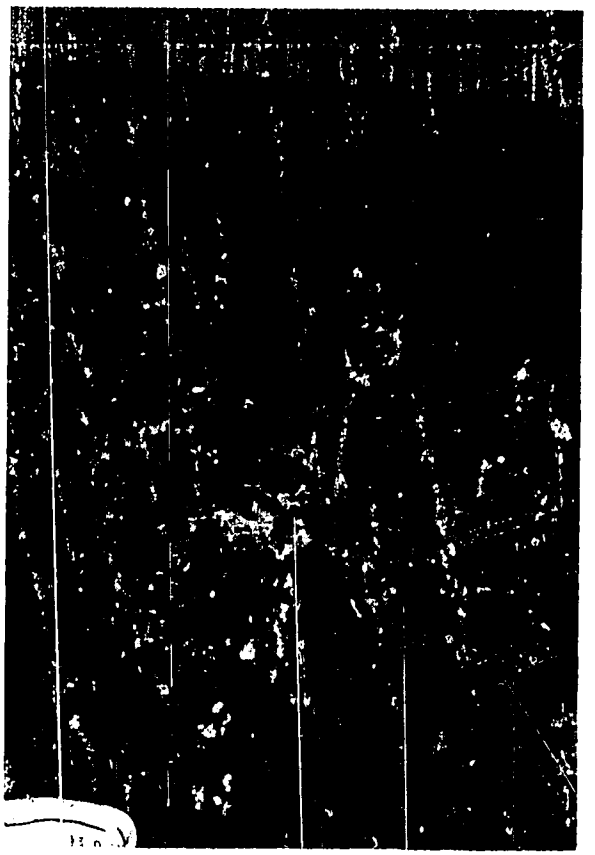
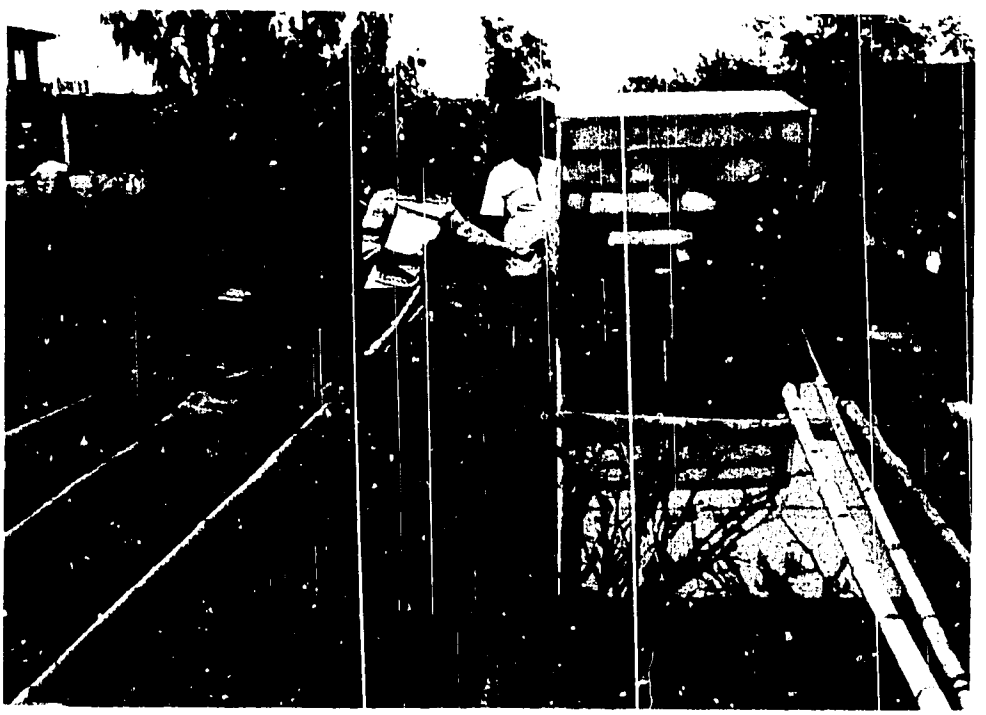
Solar Refrigerator



Drying Bins inside the
Forced Convection Solor Hut Dryer



A Solar Cabinet Dryer Field Tested at Phitsanulok

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PYROLYSIS OF RICE HUSKS

The main objective of the Pyrolysis of Rice Husk (PRH) component was to promote the application of pyrolysis technology (PT) among rice mills in Thailand. The implementation was divided into three phases:

1. The Preliminary Study;
2. The Technological Development; and
3. The Promotion Plan.

The preliminary study

The preliminary study, which covered the period from January 1982 to February 1983, consisted of a review of PT literature and PT design, development and data gathering of a socio-economic survey (for rice mills and their surrounding communities), and the fabrication of hardware.

The review of PT literature and PT development explored experimental work done in a number of developing countries, including Indonesia and the Philippines. Results of these experiments indicated that PT could be successfully developed in developing countries, including Thailand.

The field survey sampled and gathered data on 158 rice mills and 1,541 surrounding households throughout the country. The results revealed that most rice mill were either small or medium size and operated with diesel engines. There was a positive change in the attitude of rice mill owners and rural people toward PT and its products, (i.e. char briquets) after the potential benefits of PT and its products were explained to them. This suggested the possibility for positive, future acceptance of PT.

Studies on rice husk production and utilization revealed that the potential availability of rice husk in 1980/1981 (calculated on the basis of total paddy output and the average rice husk production rate per ton of paddy), was estimated to be approximately 4.54 million tons. Utilization of rice husk as fuel, which was the largest potential utilization, accounted for only 15 percent of the total amount of rice husk available.

Final analysis of findings in the preliminary study indicated that PT had its initial potential applications among diesel engine rice mills whose daily supply of rice husk was not lower than one ton.

Technological development

After completion of the field study, a prototype pyrolytic conversion system capable of processing one ton of rice husk per day was constructed using a model designed by John W. Tatom (with some modifications in the feeding system, and the char removal, off-gas cooling and cleaning units). The system served as a training facility for the engineering staff and for research and development.

In the technological development phase (which covered the period between February 1983 to September 1984), the study began with operation of the pilot of the pilot plant to determine optimum design parameters and cost data of a PT system suitable for rice mill operation.

After operating the pilot plant, some modifications on the prototype unit were made to the airgitator, the by-pass of the off-gas system, and the water condenser. These modifications were made to eliminate some problems encountered during operation. After modifications were made, system performance and operational reliability became satisfactory and were finally confirmed.

Two demonstration plants were designed and constructed at two rice mills. The installed plants included some modifications from the prototype unit. The first demonstration plant was installed at Koo Charoen Rice Mill, Amphur Wihandaeng, Sara Buri Province and the second one at the Cooperative rice mill, Amphur Wangsaipoon, Pichit Province.

An operational program was designed based on the actual working hours and days of the mills. However, the field test for each plant required two months to complete. The program covered tests of PT system performance and system reliability in operation when coupled with milling machines. It also included a training program for mill workers in operating and maintaining the system.

Concurrently, socio-economic factors were analysed. The economic analysis of the demonstration plant was based on integrating the pyrolysis system with a rice mill and evaluating the financial gain from the earnings in oil saving and selling the char and oil products. The findings indicated that PT could and should be applied and promoted among rice mills.

The promotion plan

An integrated promotion plan for the pyrolysis technology was prepared and was to be implemented by NEA with technical support from TISTR. The promotion plan covered the following key issues: promotion strategies, financial policy and strategies, infrastructure requirement, institutional arrangement and a detailed promotion program.

Conclusions

The following conclusions were drawn from the foregoing discussion:

The preliminary study

- A systematic field survey of 158 sample rice mills throughout the country revealed that most of the rice mills were of small and medium sizes with daily milling capacities ranging between less than 5 tons/day to 20 tons/day of paddy. The daily and yearly operating time of the mills depended on the supply of paddy in each region, normally ranging between 3 to 24 hours and 160 to 240 days respectively, with the overall average of 12 hours and 200 days respectively.

- Study on the energy use patterns of the surveyed rice mills revealed that more than 73.4% of them used diesel engines while the remaining 11.4% and 15.2% used steam engines and electric motors respectively. The number of the diesel engined rice mills, over 92.8% were of small and medium sizes using engines with rating power of 30 hp or less.

- It was also determined that the small and medium mills used diesel engines as high as 88.8% and 76.8% respectively, while the majority of large mills used steam engines, which accounted for 66.7%. Obviously, the oil consumption by rice milling industry was mostly shared by the small and medium mills.

- The diesel oil consumption per ton of paddy for the milling processes was determined to range from 7.8 to 10.8 liters. Using the average figure of 8.5 liters and assuming an efficiency of 25% for a diesel engine, the energy requirement was determined to be 19,913 kcal/ton.

- Interviews of rice mill owners concerning their attitude towards PT revealed that most of the owners of the diesel engined rice mills showed very strong interest in PT while those of the steam and electric mills showed less interest.

- Study on the marketability of char briquets revealed that more than 75% of the 1,541 surveyed households used wooden charcoal as their major cooking fuel with the average monthly consumption of 51.8 kg per household. This indicated a good market potential for the rice husk char briquets considering the forecasted trend in a shortage of wooden charcoal in the near future.

Technological development

- After modification in the pyrolysis system design and operating with the following field conditions--8 to 11% moisture content of the rice husk feed; varying the rate of input, 49.1 - 53.7 kg/hr; air-to-feed ratio, 0.68 - 0.73; and a char discharge rate of every 5 minutes for 2 seconds--the pilot plant was capable of converting one ton of rice husk per day into combustible char, gas and oil with the yields ranging between 35.5 - 39.8%, 41.8 - 50.9%, and 13.5 - 18.4% of the feed respectively.

- The Koo Charoen demonstration plant, which was developed from the pilot plant and adapted to suit the mill's conditions was capable of converting 1 - 1.5 tons of rice husk into combustible char, gas and oil with the yields ranging between 43.7 - 47.0%, 40.0 - 45.6% and 3.7 - 6.7% of the feed respectively, and with a loss of approximately 11% of the process.

- Due to the time constraint, there was still no available data from the demonstration plant operation at Pichit Province.

- The energy input required for the demonstration plant operation, was determined to be 42.5 kWh/day and cost about 74.38 baht/day (1.75 baht/kWh) or US $ 3.23/day (about 8 US cents/kWh). The total energy output of the pyrolysis system was determined to be approximately 413 Mkcal/yr.

- The gas produced was used as a diesel oil substitute for powering the mill's engine. After being coupled with a diesel engine of 280 hp and 8 pistons, the pyrolysis system demonstrated a sustained maximum 35% of diesel oil reduction at the normal milling rate of 2 tons/hr.

- The test on utilization of char briquets as a cooking fuel in comparison with wooden charcoal revealed that with the mass samples of one kg each, both had nearly the same temperature peaks and combustion periods ranging from 840 - 880°C and 1.5 - 2.0 hr respectively but the temperature of the char briquet samples decreased slightly faster than that of the wooden charcoal.

- The test on utilization of tar oil as fuel of the open furnace revealed that the mixture of tar oil/furnace oil in the ratios of 20:80, 30:70 and 40:60 by volume could be easily combustible, except for the ratio of 50:50 by volume.

- It was determined that the cost of the demonstration unit could be paid back within 2 years with a 61.8% annual internal rate of return, based on the following field conditions:

  - Rice mill operating with diesel engine of 280 hp;
  - Capacity : 40 tons/day;
  - Working time : 10 hr/day and 300 days/yr;
  - No. of workers : 2 persons;
  - Capital cost of pyrolysis system : 194,600 baht;
  - Working life of the system : 5 yr;
  - Income : Char 124,020 baht/yr (1.50 baht/kg);
    Pyrolytic oil 11,280 baht/yr (2.00 baht/l.);
    Saving in oil 103,485 baht/yr (35% oil reduction).

- After the plant demonstration and training program were completed, the rice mill owners from every part of the country showed much interest in the PT system. Many of them inquired by letter or came to TISTR to observe and to request more information.

The promotion plan

- During the period of the promotion, NEA will play the role of administrative coordinator between the government agencies and private sectors concerned. NEA, in collaboration with TISTR, low-interest rate finance corporations, and regional rice-mill associations, will be an organizing committee for arranging seminars and workshops on PT. This will introduce the new technology to interested rice mills, as well as assess the potential demand for the applications, which will be very helpful in making financial arrangements for investment in PT.

- For technical support, TISTR will be responsible for the transfer of the developed technology through equipment manufacturers by providing them with engineering designs and consultancy. Furthermore, TISTR will also provide engineering and cost data as well as arrange a training program in the operation and maintenance of the pyrolysis system to the rice mills where PT installation is requested.

Recommendations

- Since, at present, there are more than 40,000 rice mills operating throughout the country, and only two demonstration sites of rice husk pyrolysis, the current situation is inadequate to promote the technology; thus, the period for the demonstration should be extended until at least 3 demonstration units are installed in the Northeastern and the Southern regions of the country.

- For the financial arrangement, NEA will approach low-interest rate financial sources proposing the investment project with the technical data back-up from TISTR. In case some rice mills could partly afford the investment themselves, NEA might subsidize them by providing the balance. The subsidy might be provided by requesting support from the government or international organization funds. By these means the investors would take part in the responsibility for the investment. In addition, tax incentives should be allowed to encourage more investment.

- Since PT can process a wide variety of organic materials, it has an extensive application in other areas of energy sources, such as solid waste disposal, and the production of industrial feeds. Further investigation on other applications of pyrolytic products, i.e., char, gas and tar oil, is therefore strongly recommended.

- In addition to its application among rice mills, PT might be also applicable in terms of process heat to other agro-industries, such as the cooconut-milk production industry, and saw mills where the industrial wastes are adequate to be utilized as feeds for PT. In case the areas lack electric supply but considerable amount of wastes as feeds for PT are available, the application of PT for generating electricity should be further investigated, particularly the scale of economy.

- Since the biomass gasification technology, at present, has been proved feasible only for using wooden charcoal as its feed, a costly process still, this processing cost could be reduced by the replacement of wooden charcoal with the rice husk char briquets produced from PT.

- Eventually, the cost-reduction in the pyrolysis system operation should be further investigated, probably by using the energy recyling method.

NOTE: For the report in its entirety see, "Feasibility Study on Rice Husk Pyrolysis Technology for Rice Mill Applications in Thailand", Published by the National Energy Administration, USAID, under the Renewable Non-conventional Energy Project #493-0304, Bangkok, Thailand, 1984.

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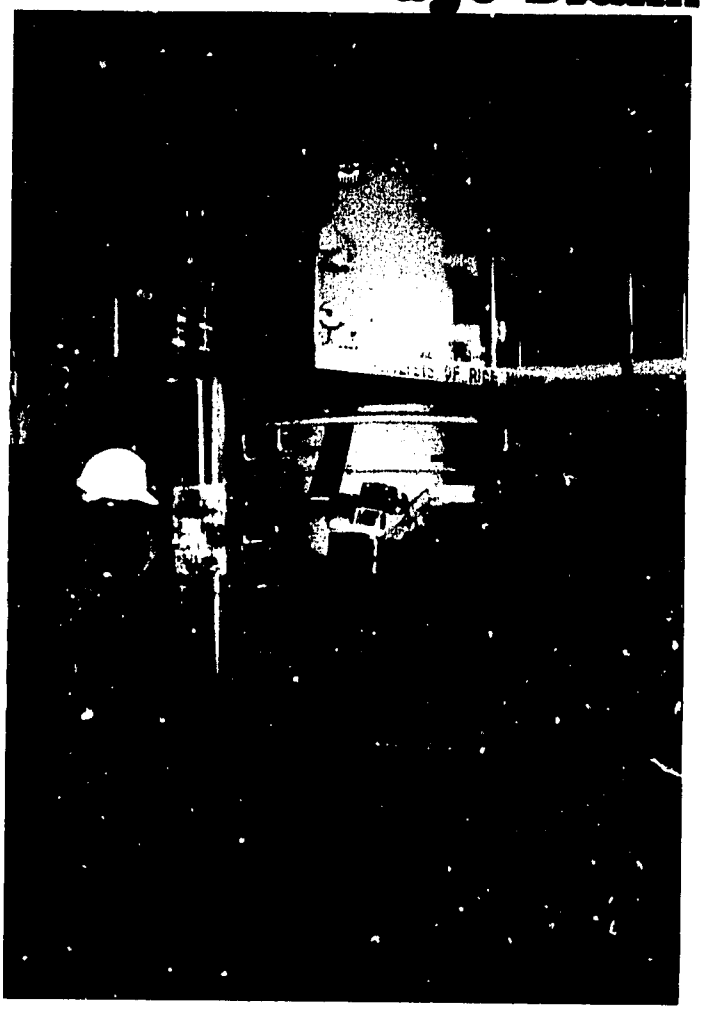
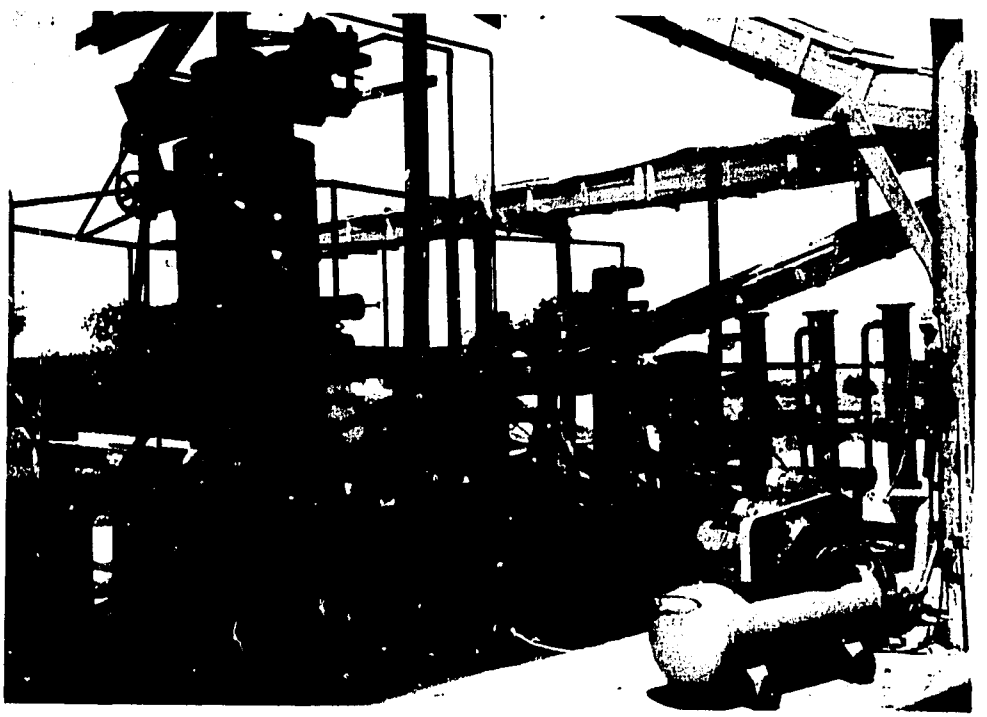


TISTR Pilot Plant of Rice Husk Pyrolysis



Demonstration Plant of Rice Husk Pyrolysis at Sara Buri Province

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INDUSTRIAL BIOGAS

With the energy crisis and the deficit in foreign exchange, research and development on nonconventional energy technologies has been initiated in Thailand. Biogas, which is one of the well known technologies, has been demonstrated in most of the developing countries by utilizing animal dung as a biogas source for cooking, lighting, water pumping, etc. Most of these biogas plants are family sized plants. There are very few large-sized biogas plants that still use animal dung.

However, it is realized that some types of industrial wastewaters with high organic concentration can also be utilized for biogas production and be treated simultaneously. The National Energy Administration (NEA) initiated the Industrial Biogas Project with the purpose of trying to demonstrate the technique, as well as economic feasibility of biogas technology for industrial wastewaters. The laboratory scale test was carried out by Mahidol University under contract with the NEA. Five types of wastewaters, namely, tapioca waste, sodium monoglutamate waste, canning food waste, and dairy waste were selected for preliminary testing to find the most suitable one for gas production and gas composition.

In the preliminary test based on chemical oxygen demand (COD) and biochemical oxygen demand (BOD), it was found that sodium monoglutamate waste and tapioca waste are suitable for laboratory scale experiments. The anaerobic filter process was applied to sodium monoglutamate waste. The results of gas composition indicated that the biogas produced from sodium monoglutamate waste is not suitable. Moreover, the clogging of the system showed that the process is not practical.

The contact anaerobic process was applied to tapioca waste and it was found that gas production from tapioca waste is possible. However, in analysing the data obtained from Mahidol University, the author found that the gas production from tapioca waste is much lower than that stated by Mahidol University--20 cubic meters of gas produced per day, rather than 150 cubic meters of gas produced per day.

For the economic analysis, Mahidol University recommended that the minimum size of the digestion system was to be about 5,000 cubic meters with an investment return back period of 12 years. However, the investment cost is too high for tapioca factories in Thailand. With 50 cubic meters of digester, as was proposed for the demonstration plant, it was found that the return back period could not be obtained within 30 years, even with 8 percent interest without inflation. In addition, the production cost of biogas based on 20 years of equipment service life is still higher than that of fuel oil.

However, because of Thailand's interest in energy conservation, as well as the concern for treatment of industrial wastewaters, this plant should be constructed. Yet, in the future, the ones who invest for biogas construction systems are individuals who would be interested in a return of investment. Of course, the results of this experiment for consideration by individuals for this type of biogas production is not economically feasible. The cost of the minimum size of the digestion system to get a return back period is too

high and the return back period is too long. Thus, the demonstration of the biogas plant might fail even though the technology is feasible.

Conclusions

- In the preliminary analysis and laboratory scale experiment, tapioca waste was found to be the most suitable waste for generating biogas in terms of quantity of gas produced and quality of methane gas composition.
- The anaerobic filter process is not suitable for high concentrations of waste. The system is not able to resist the high organic loading.
- The variation of temperature during the laboratory scale experiment was not controlled.
- The gas production from the contact anaerobic process is about 3 times the volume of feeding waste with 75 percent of methane gas produced.
- The gas production for 50 cubic meters of digester could not be more than 25 cubic meters of gas per day, rather than 150 cubic meters per day as reported by Mahidol University.
- The minimum size of a contact anaerobic system is 2,500 cubic meters for a return back period. However, the size of digester for a 12 year return back period is 5,000 cubic meters of digester.
- The comparison of production cost between fuel oil and biogas produced from 50 cubic meters of biogas plant calculated at various interest rates showed that biogas produced from tapioca waste is not competitive with fuel oil. In addition, it is not possible to have an investment return back period within 30 years.
- Although these results indicate that the treatment of industrial wastewaters by the anaerobic system is not economically feasible at this time, the results indicate that the technique is possible.
- This research adds to the knowledge of the NEA officials in their search for adequate treatment and utilization of Thailand's industrial wastewaters using the anaerobic process.
- The NEA will continue to explore the use of high organic load factory wastewaters by importing cost effective anaerobic systems.

Recommendations

- The surrounding conditions for the experiment should be the same, so that the results are reliable and can be used to study the effect of the process.

- The parameter which should be emphasized for this experiment is the control of various temperatures.

- The anaerobic contact process system designed by Mahidol University consisted of a gas holder made of stainless steel which is very expensive. It might be advisable to use a compressor for collecting gas at certain levels of pressure and use a smaller gas holder as a pressure control.

- The tapioca biogas demonstration plant should be constructed to explore technical feasibility of this type of biogas plant. It would be the prototype for a biogas treatment plant utilizing industrial wastewater in the future. This phenomenon might gear up individuals, institutes and other concerned agencies to find or seek new technologies concerning biogas and the treatment of industrial wastewaters at a feasible economic level.

- The pollution of the environment is of major concern to the Government of Thailand, therefore, the research in the treatment and utilization of industrial wastewaters should be continued until solutions to the problems are found.

NOTE: For the report in its entirety see, "Industrial Biogas: A Feasibility Study of Waste Utilization from Agro-Industry in Thailand", Published by the National Energy Administration/USAID, under the Renewable Non-conventional Energy Project #493-0304, Bangkok, Thailand, 1984.

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STOVE IMPROVEMENT

Energy for household cooking in Thailand depends largely on biomass mainly in the form of wood and charcoal. The annual consumption of both fuels in terms of solid wood is approximately 40 million cubic meters, with an estimated value of well over 7.5 billion baht. If this quantity of wood fuel were to be provided by commercial fuels such as kerosene, LPG and LNG, the national spending on such imports would be at least three times higher. Furthermore, many problems would exist both with effectively distributing these forms of energy to rural areas, as well as with its prohibitive cost.

Statistics on wood consumption of the country reveal that the use of wood for fuel is approximately 75-80% of all uses (with such purposes as construction and industrial applications comprising the remainder). This consumption ratio indicates that the country's dependence on wood fuel is likely to persist for a long time to come.

The present scarcity of fuelwood has already appeared in many areas of the country. This will occur more frequently as the natural forest diminishes and the population increases. In order to correct this problem, in addition to planting more fast-growing species of trees, conservation through the improvement of inefficient cooking stoves is necessary. As a consequence the Cooking Stove Improvement for Household Use Project was launched.

The objectives of the project were:

a) to investigate the performance of existing stoves currently used in Thailand,
b) to make necessary improvements on each type of stove (charcoal, wood, and agriresidue) for better fuel efficiency and ease of operation,
c) to establish improved stove production techniques suitable for small-scale rural industries,
d) to disseminate information, technology and/or improved hardware to stove users, manufacturers, and the general public, and
e) to increase the number of trained personnel and institutional research facilities for future campaigns investigating efficient biomass cooking stoves.

This project component was operated by the Forest Products Research Division of the Royal Forestry Department. The operation phase was started in March 1982 and ended in September 1984. Activities undertaken included collection and selection of commercial stoves, stove development to yield better design, prototype testing, improved stove production and fabrication, and promotion of the improved final models.

Accomplishments can be summarized as follows:

1) The performance of household cooking stoves in Thailand (both commercial and user-built models) was investigated.
2) Based on the heat utilization efficiency (HU) rating under the same test standard, it was found that the average HU's for LPG, pressurized kerosene, charcoal bucket, nonchimneyed wood, chimneyed wood, nonchimneyed rice husk, and chimneyed rice husk stoves were 46, 48, 27, 20, 12, 16, and 5% respectively.
3) The improvements on the five generic types of biomass stoves mentioned above have resulted in HU increases of 26% for charcoal, 35% for nonchimneyed wood, 58% for chimneyed wood, 20% for nonchimneyed rice husk, and 100% for chimneyed rice husk stoves as compared with the average existing models.
4) In addition to the HU increase (indicating the net increase in work output per unit fuel input), certain stove features were also improved -- particularly the stove rim design to accommodate various sizes of pots and pans, fire-resistant characteristics of pottery liners for charcoal and wood stoves, and increases of their service lives.
5) A better clay raw material for pottery liner stoves was identified and a production technique suitable for rural industries developed. A trial production by village stove makers employing this technique was successful. 2000 charcoal and 1200 wood stoves of acceptable quality were obtained with good production precision.
6) The component conducted nine improved stove training courses for concerned rural government officials and rural stove users. The reception for the improved models (particularly charcoal and nonchimneyed wood stoves) was very encouraging. The reception for rice husk stoves was also enthusiastic, but was restricted to a few rural areas only.
7) During the trial promotion, approximately 1500 charcoal, 800 nonchimneyed wood, 150 nonchimneyed rice husk, and 50 chimneyed rice husk stoves were distributed to trainees, to interested government and private organizations, and to individual users upon request.
8) As a result of the project implementation, a modest stove laboratory, adequately equipped with basic facilities for future work, was established at RFD.

Conclusions

- As a part of institution strengthening, the component has succeeded in establishing a cooking stove testing laboratory at the Forest Products Research Division, Royal Forest Department. Through project funding, the laboratory was equipped with invaluable, basic test instruments and facilities--including a microcomputer system for future applications.

• Long-term training of project personnel to increase their future capabilities was minimum because time was short (30 months) and they were needed on site to carry out project tasks. Therefore, all technical personnel were indispensable for project implementation. They could not be spared for long term training.

• The component has produced five generic types of improved cooking stoves: namely, the charcoal bucket stove, wood stoves with and without chimneys, and rice husk stoves with and without chimneys. The absolute heat utilization for charcoal and both types of wood stoves increased up to 7% over that of the average commercial models. Further, an increase of 5 and 3% was achieved with rice husk stoves with and without chimneys respectively. In terms of comparative efficiency increases, the charcoal stove reached a 26% increase over the average commercial models, while for wood stoves with and without chimneys they were 58 and 35% respectively. The increase for the rice husk stove with chimney was 100%, or double the efficiency of the average commercial models. The rice husk stove without chimney had the least increase, 15 - 16%.

• The investigation conducted on existing commercial stoves revealed that fuel efficient cooking stoves for charcoal, wood, or rice husk are rare. The laboratory tests have led to the identification of the stoves' critical physical parameters. They consist of stove weight; exhausted gap/area; combustion chamber capacity; rim design for proper fit of variously-sized pots and pans; grate-to-pot distance; grate parameters such as hole area, hole size and distribution, and thickness; height of chimney, and flue gas baffle (for chimneyed stoves). Other strong factors also influencing stove performance are external variables--fuel load or fuel feeding rate, amount of water to be boiled, and the wind factor. The information obtained was later used for redesigning the improved stove models.

• Good quality clay material suitable for stove manufacturing has been identified and a production technique has also been developed for small-scale and home industries. Local stove manufacturers in one district of Roi-et Province were trained without any difficulty in this technique of stove production. Improved stoves, particularly charcoal and nonchimney wood models, are heat refractory and can withstand thermal shock much better than present commercial ones. In addition, the application of the internal mold has greatly improved the precision necessary to control the critical internal dimensions. This method was found to be superior to the traditional one using an external mold which hardly controlled the internal dimensions.

• The production cost of the improved models as described in (2) above presently is approximately 2.5 times more than the cost of the poorer quality commercial models. However, when compared with top quality charcoal bucket stoves sold in the market, the improved models' cost is 25 - 30% lower. Therefore, in long-term commercial production, the improved models will be competitive when production increases and more improved stoves reach the market.

• So far, nine improved stove promotion and training programs have been carried out among villagers at various places around the country. The reception for the charcoal bucket and the non-chimney wood stoves was very good, while the good reception of the rice husk chimneyed stove was limited to a few localities where only rice husk is available. The chimneyed wood and non-chimneyed rice husk stove are of less interest to rural users than the charcoal bucket and the non-chimneyed wood and the rice husk chimneyed stove. It is believed that with good follow-up and promotional effort, some of the improved developed models will withstand harsh use and serve users well in rural kitchens. However, these long-term results are yet to be seen.

• Because of time constraints, the project had a limited time to approach manufacturers on a large scale. However, among a few large manufacturers in the Central area, the response to the idea of mass production of the developed models was not enthusiastic. This lack of enthusiasm is perhaps a result of stove manufacturers being accustomed to the production of their rough products and being reluctant to manufacture stoves with which they have little or no experience. Moreover, they probably want to see the market for high quality, efficient stoves develop first before committing their resources to their production. Therefore, more time and more education are needed for them to change their attitude and adapt their production techniques.

Recommendations

• Because stove development and promotion involve the social customs and habits of millions of people in Thailand and around the world, it is highly recommended that stove research and development be carried on to further improve present designs and find more alternatives for users.

• Stove development should emphasize each generic type of stove; namely, charcoal, wood with and without chimney, and agriresidue stoves with and without chimney so that users have choices.

• Stove research and development must not only emphasize the good conversion efficiency, but it must also facilitate ease of use and other cooking functions, without causing undue change in people's cooking habits.

• Stove promotion is a most difficult activity. It will take a great deal of time and resources. Therefore, continuous effort must be made for at least five years with reasonable financial and human resource support in order to see a real impact among 6 million rural users.

• In Thailand there are quite a few researchers and interest groups working on stove development and promotion. Unfortunately, all lack guidelines and coordination. For national stove programs to be directed toward this common goal, leading government agencies are needed to provide close coordination.

• During the course of stove development, many contacts were made with experienced stove manufacturers. It was found that, regardless of their long experience, their basic understanding of good stove configuration, design and its performance was very much lacking. This problem was also manifested in the presence of a large majority of poor quality and less efficient commercial stoves in the market. Therefore, it is strongly recommended that concerned government agencies take an initiative toward arranging formal training programs for the promotion of the essential, scientific knowledge required among stove manufacturers. Incentives or approaches such as offering a certificate and/or reward to manufacturers of efficient stoves would be a highly motivating factor.

• The lack of understanding among users on the criteria for selection and use of efficient cooking stoves was also evident. Therefore, the concerned government agency should establish a long-range,adequately funded educational campaign program for efficient stoves--particularly through primary and secondary school systems.

• The cost of improved design stove production is still high. If simple hydraulic molding can be developed and employed at the village level, production costs can be greatly reduced. Under these conditions stove dimensions will be more precise and the production rate will be increased significantly.

• Selection of clay raw material and improvement of the clay mixture and firing to attain a product with fire resistant characteristics (particularly, the charcoal stove body) are essential to a stove's long service life. The weight of the stove also needs further reduction (to achieve peak performance with even lower charcoal loads).

• The improved non-chimneyed wood stove is quite efficient for the present developed model. It can conveniently be used to replace three-rock stoves. However, the same problems exist in its mass production techniques as exist for the charcoal stove.

• Smoke in the kitchen is a problem inherent in non-chimneyed wood stoves including the three-stone and open fire. Research should be carried out in Thailand to determine whether smoke from undeveloped and even developed stoves (which noticeably gives less smoke over the undeveloped ones), has any significant effect on long-term health of users.

• Up to the present time, the one hole chimneyed wood stove has attained an efficiency up to only 18-19%. In addition, there are problems fitting pots and pans to this stove. Therefore, it is recommended that development on this type of stove be continued in order to improve both heat utilization efficiency and compatability with various pots and pans. Moreover, the stove material (as in the case of the non-chimneyed wood stoves and the charcoal stove) should also be investigated.

• Even though, at present, the chimneyed rice husk stove is still not popularly used in Thailand, the chance for this stove to become popular in certain regions is high. This is because it can use granulated fuels other than rice husk (such as sawdust, peanut shell, seed waste, household biomass

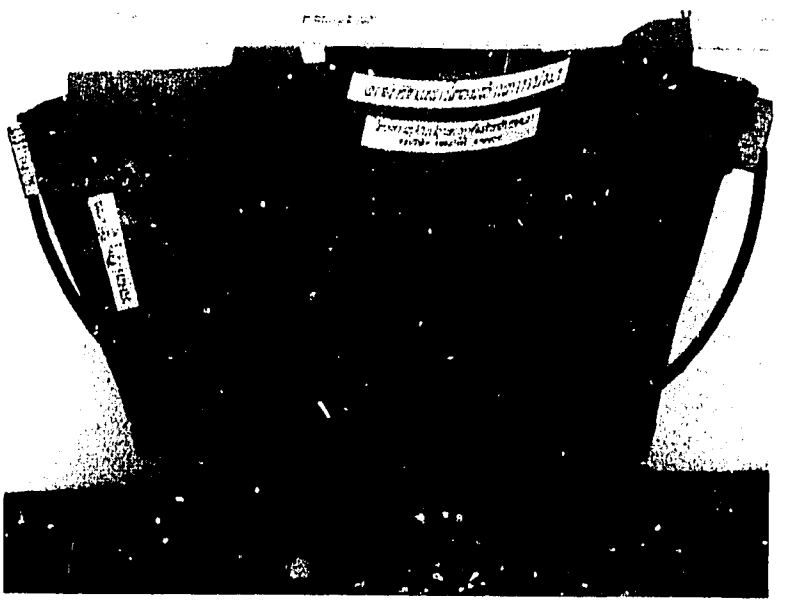
scraps, etc). There are several further improvements that need consideration. These include the improvement of the stove's configuration to fit various pots and pans and reduction of its weight so that sometimes it can be moved around the house (yard) when needed. For two people to carry the stove, the weight should not exceed 50 kg.

- The experience gained from the stove promotional campaigns among rural users, even in its short duration, strongly indicated that there is a good chance of success in replacing relatively inefficient stoves among 6 million rural Thai families with efficient stoves. It is, therefore, recommended that the government support a nationwide efficient stove promotional campaign for users and manufacturers as soon as possible.

- Since better biomass cooking stoves, in part, mean better living for millions of rural families around the world, the idea of continuous development to attain even better performance than the present developed models should be the challenging subject among applied research scientists and concerned institutions.

NOTE: For the report in its entirety see, "Improved Biomass Cooking Stove for Household Use", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Testing the performance of sample biomass stoves



The Improved Charcoal Bucket Stove

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CHARCOAL IMPROVEMENT

Rural development has always been treated as a first priority by all ruling governments of Thailand. Even though progress has been made in solving these socio-economic problems, some of the development, unfortunately, has been at the expense of the environment, particularly soil, watershed, and natural forest.

A nation-wide campaign for tree planting in rural communities was hindered by the fact that many people cannot foresee an economic benefit from short rotation forestry activity. At the same time, energy from wood is still essential for the well-being of the community. More than 3 million metric tons of charcoal were used for household cooking (as found in this project survey) with a value of at least 4,500 million baht annually. This kind of high-grade biomass fuel cannot be effectively replaced by any kind of energy within 10-15 years.

The Charcoal Production Improvement for Rural Development Program, therefore, has as its purpose the creation of a market to absorb such forest produce from farmers in large quantities. In order to introduce and implement this concept to rural villagers and farmers, vital information and technical expertise on efficient charcoal production must be first developed. This technical cooperation project was designed with that purpose in mind.

The specific objectives of this project were:

- To establish a country status report on charcoal production, demand and supply, and distribute it throughout the country;
- To investigate all existing charcoal production methods found in Thailand and some methods from abroad;
- To improve charcoal kilns and production techniques so that yield and quality can be optimized with less capital and operating costs;
- To promote and extend such charcoal production technologies to rural charcoal makers and rural government agencies; and
- To increase research facilities and number of personnel for future campaigns on renewable energy from biomass.

This project component was operated by the Forest Products Research Division of the Royal Forest Department. The operation phase was started in April 1982 and ended on June 30, 1984.

Accomplishments of the project can be summarized as follows:

1. A formal report investigating the present status of charcoal production, consumption, and distribution in Thailand was produced.

Previous Page Blank

2. The study evaluated 13 charcoaling methods; three non-permanent techniques, i.e., earth mound, rice husk mound, and sawdust mound; four portable metal kilns, i.e., Tonga, Single Drum, Double Drum, and Mark V; and four permanent installation kilns, i.e., local mud beehive, local brick beehive, Brazilian brick beehive, and the Philippine Hot Tail.

3. Test results indicated that permanent kilns were superior to both metal kilns and nonpermanent mound types in charcoal yield and quality.

4. Improvements in firing techniques and methods of kiln construction (for local mud and brick beehive kilns) resulted in shorter firing time and charcoal quality consistency. The average obtainable yield was 35-40% of oven-dried wood raw material, depending on species and age. The overall energy conversion efficiency was as high as 55%-60%.

5. Nine promotional training programs on improved charcoal production technology employing both mud and brick beehive kilns were completed. The training involved 307 trainees from rural development organizations and rural villagers/ charcoal makers. As many as 34 kilns with a $2m^3$ capacity were built during promotion and training.

6. As a result of research and development activities required during project implementation, the Charcoal Research Center was established. This unique center, as well as the RFD central laboratory, are well-equipped for future research and development and promotion training.

Conclusions

The implementation of the charcoal improvement component was actually carried out for 26 months between April 1982 - June 1984. The operation can be considered highly successful in terms of the objectives and the scope of work. Conclusions concerning activities and findings can be drawn as follows:

- The Charcoal Research Center has been successfully established to deal with charcoal improvement for rural development. The Center and the RFD Central Laboratory were well provided with scientific equipment to cope with present and future research, development and promotional training.

- The nationwide charcoal survey (to determine the status of charcoal production, distribution, and consumption) was completed. A full, separate report was published. This survey revealed that Thailand's charcoal consumption is as high as 3 million metric tons annually with an estimated minimum market value of 4,500 million Baht per year.

- 18 kilns of various sizes and 13 models (both local and exotic designs) were built and tested to determine their appropriateness for conditions in rural Thailand.

- Research on various types and sizes of kilns has shown that permanent charcoal kilns provide the highest charcoal yield and conversion efficiency, especially the mud and brick beehive kilns.

- The 2 to 8 m^3 capacities of both types of beehive kilns are more suitable for rural families and/or communal village practices when such factors as charcoal quality and quantity, ease of operation, firing duration, and capital investment are considered.

- The moisture content of the wood had very little influence on charcoal yield and conversion efficiency, but the moisture content prolonged the operating time significantly.

- Continuous firing "until the kiln is closed" versus "until white thick smoke appears" showed that both firing methods did not significantly affect charcoal quality or quantity.

- Increasing the heating rate of the kiln within the temperature range of 30 - 400° C. significantly enhanced the charcoal output.

- The extension of chimneys reduced the operating time significantly under carefully controlled conditions; i.e., the chimney should be extended until white thick smoke appears or until carbonization begins.

- The average charcoal output of wood specimens from eleven species revealed a difference in charcoal quality and quantity. The range of both charcoal yield and conversion efficiency differences was about ten percent. However, a few species provided charcoal yields that deviated from the average.

- The charcoal outputs within the nonpermanent kilns -- earth mound, rice husk mound and sawdust mound -- were slightly different. The operation must be done carefully to avoid overcombustion. The average charcoal yield and conversion efficiency were better than the mobile kilns.

- Although the capital investment of the nonpermanent kilns is negligible, the cost of operation was rather high.

- The mobile kilns such as the Mark V, Tonga, Single Drum and Double Drum are less suitable charcoal kilns for Thailand's rural people because of the high capital investment required and the poor quality of charcoal that was produced.

- Although the production rate of the mobile kilns was the fastest, the average charcoal yield was the lowest and mobile kilns produced more fine and ash.

- The promotion training of improved charcoal production technology (employing mostly mud and brick beehive kilns) was launched from January to June 1984. So far, three two-week intensive training courses for government rural development and NGO officials were conducted at the Center and six one-week training courses for village leaders, rural charcoal makers and prospects were conducted at the village level around the country with very close cooperation from the NEA, the Regional Energy Center and Mobile Development Units of the National Security High Command. So far, as many as 34 mud and brick beehive kilns have been built at various places during the promotion campaigns.

- The results of training (including actual field practices as viewed by most charcoal trainees at the end of the course) indicate that the chance of acceptance of these improved technologies among rural charcoal makers is high, if wood is available. In addition, the introduction of the improved charcoal cooking stove has greatly helped them focus on production, conservation and use of charcoal.

Recommendations

In implementing the Charcoal Improvement Project, a considerable investment was made both in financial and technical support. Even though the operation has attained its objectives and targets of the overall project, there still remains a great deal of future work that should be carried out within a certain time frame. The charcoal technology developed under this Project would be deemed meaningless unless it has found its place in rural areas and becomes widely practiced. In order to achieve this goal, therefore, the following recommendations are proposed:

- Since the consumption of charcoal for cooking in Thailand is very high and effective replacement by other fuels cannot be foreseen within the next 10-15 years, government efforts should concentrate on a strategy to implement an integrated program on fuel wood production and improved charcoal making technology in rural areas. This program not only will help alleviate the future shortage of charcoal and retard the rate of importation of cooking LPG but will also create more woodlots, a better environment, and more jobs for rural people without having to rely heavily on the natural forest.

- Information and vital data gathered during charcoal promotional training of village people, even though limited, have indicated that establishing small tree farms to make charcoal for sale can be a very good alternative for those depressed cash crop growers (who are suffering from both low product price and rapid soil depletion). However, the problem

still lies with educating farmers to believe in this technology through demonstration and proof. The government, therefore, should not be reluctant to carry out trials. If proven, rural farmers can have another choice for making a living in the immediate future.

- While keeping the production of more fuel wood from tree farming in mind, the diffusion of improved charcoal technology can be spread throughout the country through:

  a. Training of selected village leaders and rural charcoal makers in methods of making better charcoal (using locally available kilns and/or introducing kilns) with improved firing techniques as well as better fuel wood preparation prior to kilning.

  b. Charcoal Research Center initiated training of officials responsible for rural development and private interest groups on appropriate methods of charcoal making.

  c. Exhibition and demonstration of efficient charcoal kilns as a follow-up program in selected villages and at the newly-established Thailand Regional Energy Centers.

  d. Public compaigns for improved charcoal production methods, through manuals, pamphlets etc., to be distributed to schools, village libraries, universities and institutions responsible for rural development.

  e. Creation of public awareness, particularly among charcoal consumers, on criteria for the selection of good quality charcoal and its more efficient use with better stoves.

- Research and development activities directed toward even better technology for charcoal conversion from wood should be continued -- particularly with the popular fast growing species. In addition, the recovery of charcoal fines in large-scale commercial mangrove charcoal production and the improvement of inferior physical properties of light-weight charcoal (from rubber wood and from low-medium density fast-growing species) briquetting techniques should be pursued.

- Charcoal is an important carbon source for numerous industrial applications such as steel smelting, calcium carbide, activated charcoal, carbon black, etc. At present, its use has been limited because of uncertainty in constant supply, difficulty in procuring charcoal in large quantities, variability in charcoal quality, and lack of appreciation or support to develop such an indigeneous renewable product. To encourage these potential applications, future charcoal research and development should be promoted -- both on various charcoal end-use specifications and standards and on charcoal derived end-products development.

NOTE: For the report in its entirety see, "Charcoal Production Improvement for Rural Development in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Previous Page Blank

Construction of a 2 m^3 brick beehive kiln

Firing of brick beehive kilns during training at Saraburi Charcoal Research Center.

WATER LIFTING TECHNOLOGY

In this study the results from the implementation of four types of water pumping systems are presented. These include the solar pumping, wind turbine pumping, gasifier, and biogas pumping systems. Among these four pumping systems, only the solar and wind turbine pumping systems have been installed to date.

One 700-watt solar pump was installed to pump water from a ground water well at Ban Tha Yiam, Sakon Nakhon Province, for domestic consumption. The pumping volume was approximately 6m^3/day with a lifting head of 21.5m. The investment cost of this solar pump was 357,550 Baht (US $ 15,546), of which 235,980 Baht (US$ 10,260) was contributed by USAID. An economic analysis revealed that the benefit-cost ratio (B/C) of this solar pump was 0.49:1, and that the solar pumping system is not yet economically feasible. This is due to the high cost of the solar array.

The other 4,300-watt solar pump was installed at Ban Sukorn, Nakhon Ratchasima Province, to pump water from a storage pond for irrigation purposes. The pumping volume was estimated to be about 480 m^3/day with a lifting head of 5.0 m. The investment cost was 1,094,555 Baht, (US $47,589), of which 944,127 Baht (US 41,049) was contributed by USAID. An economic analysis showed that the benefit-cost ratio of this solar pumping system was 0.42:1, and that the installed system is not economically feasible.

Three windmills were installed at Ban Samoh, Yala Province, to pump water for irrigation purposes. These included two multi-blade windmills and one VITA windmill. The investment costs of these three windmills were 80,000 Baht (US $ 3,478), 56,000 Baht (US $ 2,435) and 45,380 Baht (US$ 1,993), respectively. These windmill costs were contributed by USAID. An economic analysis revealed that the wind turbine water pumping system was not economically feasible, with the benefit-cost ratio ranging from 0.47:1 to 0.81:1.

From this study it can be concluded that the solar and wind turbine pumping systems are not economically feasible at the present time due to their high investment costs. The promotion of these types of renewable energy projects should be postponed until the price of the solar array and the windmills are decreased to a certain value.

Though the installed water pumping systems were found to be not feasible from an economic point of view, there still exist some indirect benefits from such a development. These include initiating the role of cooperation in rural development, fostering close cooperation between local people and the government, and initiating the application of energy technologies for the rural people.

Previous Page Blank

Conclusions

The study on the development of these renewable evergy projects leads to the following conclusions :

The Solar Pumping System at Ban Sukorn

This solar pumping system has been planned to pump water from the Pradok Reservoir for irrigating the agricultural lands in Ban Sukorn, Nakhon Ratchasima Province. There are a total of 112 households with 646 residents in this village. Most of the villagers are farmers. Rice is the dominant crop. The system is designed so that the nominal maximum power at the standard condition of solar array (100 mW/cm^2 at 25°C) is not less than 4,300 Watts. Four sets of solar arrays, DC motors and self-priming centrifugal pumps were installed. Each solar array consists of 32 modules of solar cells. The designed pumping discharge is 480 m^3/day at 5.0-m lifting head.

The total cost of this system, excluding the cost of the irrigation canal, was 1,094,555 Baht (US$ 47,589) of which 944,127 Baht (US$ 41,049) was contributed by USAID. An economic analysis shows that the benefit-cost ratio of this solar pumping system is 0.42:1, and that the installed system is not economically feasible.

Due to a delay in constructing the irrigation canal, this solar pump has not yet been operational.

The Solar Pumping System at Ban Tha Yiam

This system was installed to pump water from a ground water well to serve the villagers in Ban Tha Yiam, Sakon Nakhon Province. There are 57 households with 347 residents in this village. Agriculture is the main occupation of the villagers. Rice is the dominant crop grown in this area. The installed system has been designed so that the nominal maximum power at the standard condition of solar array is not less than 700 Watts. A solar array with 18 modules of solar cells was installed together with a DC motor and a screw-type pump. The designed flow rate was 10 m^3/day at a 21.5 m head. However, due to an increase in the draw-down level in the ground water well, the daily pumping discharge was approximately 6 m^3/day. The results obtained from the test-run show that the overall efficiency of this system varies between 0.9-1.6%. Its value decreases as the solar panel temperature increases.

The total investment cost for this solar pumping system was 357,550 Baht (US$ 15,546) of which 235,980 Baht (US$ 10,260) was contributed by USAID. An economic analysis reveals that the benefit-cost ratio of this solar system was 0.49:1 and that the system is not economically feasible.

The Wind Turbine Pumping System at Ban Samoh

Two multi-blade and one VITA windmill were installed at Ban Samoh, Yala Province, to pump water from storage ponds for irrigating the village agricultural area. There are 204 households with 868 residents in this village. Most of them are farmers. Rice and rubber are the main crops grown in this area.

The test run of these windmills showed that the windmill speeds and the pump discharges increased linearly with the wind speed. For the large multi-blade windmill, the monthly pump discharge was 274 m^3 at a mean wind speed of 2 m/s and the value increased to 667 m^3 with a mean wind speed of 6 m/s. The overall efficiency decreased as the wind speed increased. A value of 14% was computed for a wind speed of 2 m/s. The volumetric efficiency of the pump unit was as high as 98-99%.

For the VITA windmill, the measured monthly discharge was 5,500 m^3 at a mean wind speed of 3 m/s and the value increased to 12,500 m^3 at a mean wind speed of 6 m/s. The overall efficiency also decreased as the wind speed increased. A value of 3.3% was computed for a wind speed of 4 m/s. The PVC ladder pump was used with this windmill. The volumetric efficiency was 71% at a wind speed of 2 m/s and the value decreased to 63% as the wind speed increased to 6 m/s.

The investment costs of these three windmills were 80,000 Baht (US$ 3,478), 50,000 Baht (US$ 2,435) and 45,830 Baht (US$ 1,993), for the two multi-blade windmills and the VITA windmill, respectively. These windmill costs were contributed by USAID. An economic analysis reveals that the benefit-cost ratio of these windmills varied from 0.47:1 to 0.81:1, and this showed that the wind turbine pumping system is not economically feasible.

Recommendations

The study on the implementation of these pumping systems can lead to the following recommendations:

- Since the solar pumping systems are not financially feasible (compared to diesel engine-pumping systems) at the present time, the promotion of this energy technology should be limited until the cost of the solar array is decreased to a certain value or benefit from having water for irrigation shows that it is suitable for rural development.

- More research should be conducted to investigate the performance of various components of the system, to obtain data necessary for future project designs and to study the problems which might be encountered in the operation and maintenance of such a system.

- The investment costs of the installed windmills are rather high at this time, which makes the project not financially feasible. However, the benefit-cost ratios show that the utilization of windmills are near-term feasible. Therefore, more development of the windmill should be made with an aim of reducing the construction costs and increasing the overall efficiency.

- Since there are some indirect benefits resulting from the participation of the villagers, the system should be maintained and improved so that the utilization of the water lifting technology would be self-sustaining.

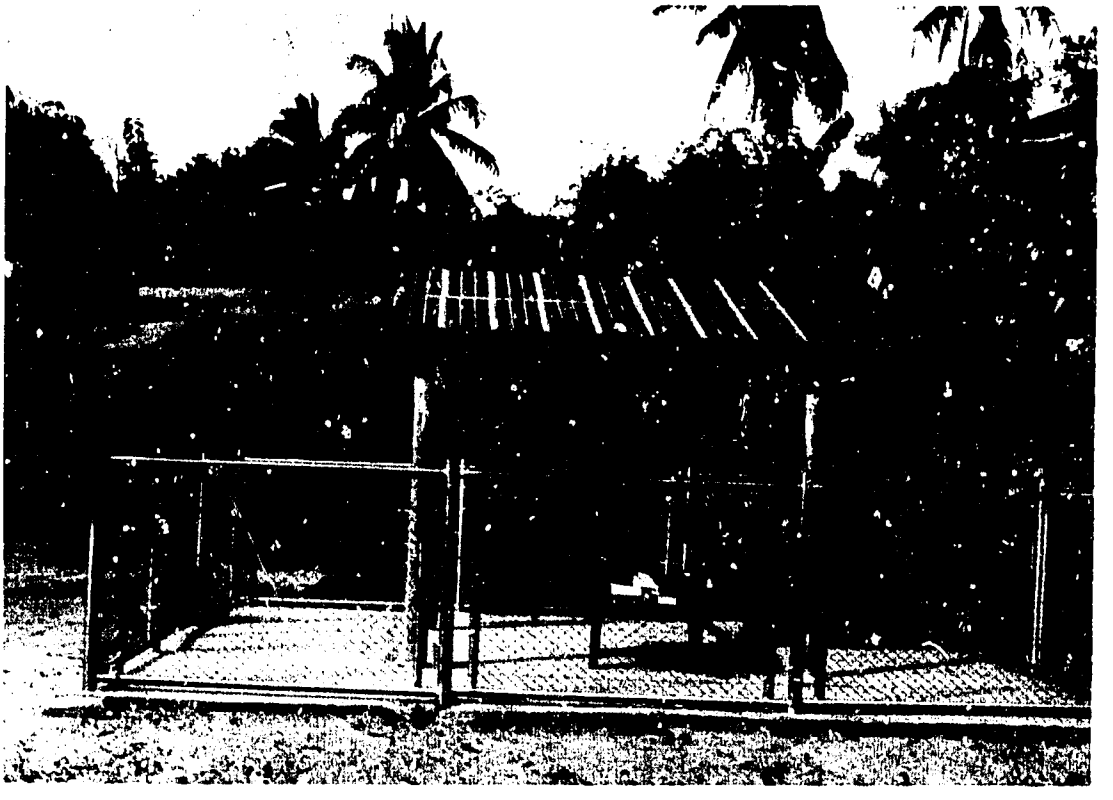
- The project would be more successful if some villagers were trained during the installation of the systems and during the testing runs.

- Monitoring activities should be continued to obtain further information concerning benefits on income resulting from providing water for irrigation since the water lifting project needs considerable time to obtain information after installation.

- Efficient utilization of pumped water should be emphasized and villagers should be educated along these lines.

- Villagers' needs and willingness to participate in the project should be carefully studied during the site selection phase in order to assure a more successful outcome during implementation.

NOTE: For the report in its entirety see, "A Feasibility Study of Water Lifting Technology in Thailand", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.



Solar pumping system at Ban Tha-Yiem, Sakornakorn.

Villager drawing water from a distribution storage tank at Ban Tha-Yeim, Sakornakorn.

Previous Page Blank

MICRO-HYDRO PROJECT

In this study the results from the implementation of four micro hydro power projects in Chiang Mai are presented. These four projects are Kam Pong, Mae Ton Luang, Huai Pui, and Bo Kaeo Projects.

The Kam Pong Project

The Kam Pong project is located in Kam Pong village, Tambon Huai Kao, Amphoe San Kampaeng, Chiang Mai Province. The catchment area at the weir site is approximately 6 km^2. The main features of the project include:

1. A concrete gravity weir, 2 m high and 15 m long, with intake structure and spillway.
2. An asbestos cement pipe headrace 0.30 m in diameter and 470 m long.
3. A penstock consisting of an asbestos cement pipe 0.30 m in diameter and 50 m in length and a 50-m long steel pipe of the same diameter.
4. A powerhouse equipped with two sets of turbines, generators, and switchboards. The installed capacity is 40 kW with a design discharge of 0.21 m^3/s and effective head of 60 m.
5. Transmission line and distribution system together with step-up and step-down transformers.

The electricity generated from the Kam Pong powerhouse is supplied to 118 households in Kam Pong village. The construction cost of the Kam Pong project is 2,656,500 Baht (US $ 115,500), excluding the labor cost and some local materials contributed by the villagers of Kam Pong. The grant from USAID to the Kam Pong Project is 1,438,519 Baht (US $ 62,544). As compared with a diesel power plant of the same capacity, the benefit cost ratio of the Kam Pong project is 1.98:1, that is, the project is considered economically feasible.

Besides the direct benefit from energy production, there exist some indirect benefits as a result of villager participation in construction work. These indirect benefits include:

1. Increasing villagers' income and upgrading their standard of living.
2. Initiating a rule of cooperatives in rural development.
3. Fostering close cooperation between local people and the government in rural development.
4. Transferring an appropriate technology to rural people.

Previous Page Blank

The Mae Ton Luang Project

The Mae Ton Luang micro-hydro power project is located in Tambon Pa Miang, Amphoe Doi Saket, Chiang Mai Province. The catchment area of the basin at the weir site is about 19 km^2. Most parts of the terrain are steeply sloping and are covered with dense forests. The main features of the Mae Ton Luang project include:

1. A concrete gravity weir, 2.20 m high and 19 m long with intake structure and sluice gate for sediment release.
2. An asbestos cement pipe headrace 0.30 m in diameter and 1,255 m long.
3. An asbestos cement penstock 0.30 m in diameter and 140 m long.
4. A steel surge tank, 1.2 m in diameter and 15.0 m high.
5. A powerhouse equipped with a set consisting of one turbine, generator, and switchboard. The installed capacity is 35 kW at a design discharge of 0.1 m^3/s and effective head of 60 m.
6. A transmission line system including transformers, high-voltage and low-voltage lines.

The electricity generated is supplied to 230 households in three villages of Tambon Pa Miang. The total construction cost is 2,577,150 Baht (US $ 112,050), of which 1,275,731 Baht (US $ 55,467) is a grant from USAID. Besides this budget, the villagers in the Mae Ton Luang project area also contributed to the project by providing part of the labor force and some local construction materials.

When considering the installation, operation, and fuel costs of a diesel power plant of the same capacity as the benefit of the Mae Ton Luang micro-hydro power project, the economic analysis shows that the benefit-cost ratio of the Mae Ton Luang project is 1.82:1. That is, the project is economically feasible.

Similar to the Kam Pong project, the participation of the villagers in the construction work of the Mae Ton Luang project also yielded indirect benefits.

The main difficulty arising in the implementation of the Mae Ton Luang project was the delay in the purchase and delivery of the generating equipment. This led to the delay in the operation schedule.

The Huai Pui Project

The Huai Pui project is located in Tambon Long Khod, Amphoe Prao, Chiang Mai Province. The catchment area is approximately 11.6 km^2. The main features of the Huai Pui project include:

1. A concrete gravity weir, 3 m high and 16 m long with intake structure and sluice gate at the right abutment.
2. An asbestos cement headrace 0.30 m in diameter and 1,450 m long. The design discharge is 0.1 m^3/sec.

3. A steel penstock 0.30 m in diameter and 165 m long.

4. A powerhouse equipped with a set of turbine, generator and switchboard. The installed capacity is 50 kW at a design discharge of 0.1 m^3/s and design head of 85 m.

5. Transmission line system consisting of step-up and step-down transformers, high-voltage and low-voltage lines.

The electricity produced from the Huai Pui powerhouse is supplied to 250 households in Tambon Long Khod. The total construction cost is approximately 2,972,000 Baht (US $ 129,217) of which 1,030,921 Baht (US $ 44,823) is a grant from USAID. Similar to the Kam Pong and Mae Ton Luang projects, the villagers in the Huai Pui project area also contributed the labor force and some local construction materials. With a benefit-cost ratio of 2.09:1, the Huai Pui project is considered to be economically feasible.

Besides the benefit from electric power generation, the implementation of the Huai Pui project also has some indirect benefits as a result of villagers' participation.

The main problems encountered in the implementation of the Huai Pui project result from the mountainous topography of the project area. This caused great difficulty in the installation of the headrace and resulted in the delay in project operation.

The Bo Kaeo Project

The Bo Kaeo project is located in Tambon Bo Kaeo, Amphoe Samoeng, Chiang Mai Province. The main features of the project include:

1. A concrete weir 2 m high and 15 m long with intake structure and sluice gate for sediment release.

2. A steel headrace, 200 m long and 0.40 m in diameter.

3. A steel penstock, 0.40 m in diameter and 600 m long.

4. A powerhouse equipped with two sets of turbines, generators and switchboard, each of which has an installed capacity of 100 kW. That is, the total installed capability of Bo Kaeo project is 200 kW.

The electricity generated from the Bo Kaeo project is mainly supplied to the Tin Mine of the Mining Industrial Organization. However, four small villages situated near the Bo Kaeo powerhouse will also be served by the Bo Kaeo project. Since most electricity from the Bo Kaeo powerhouse would be supplied to the Tin Mine, the construction work was carried out by a contractor without villagers' participation.

The construction cost of the Bo Kaeo project is approximately 6,142,500 Baht (US $ 267,065), of which 1,500,000 Baht (US $ 65,217) is contributed by USAID. The economic analysis reveals that the benefit-cost ratio of Bo Kaeo project is as high as 3.64:1. That is, the project is considered economically feasible.

The major problem encountered during the construction phase of the Bo Kaeo project was the poor accessibility to the project area, and the contractor had to construct a new access road to the site. Another problem was the delay in the purchase and delivery of a transformer which resulted in a delay in project operation.

Conclusions

In studying the project features, socio-economic characteristics, project organization and construction works, the following conclusions can be made.

- The micro-hydro component is the only one of the technology components for which the technology was actually installed, operated, and maintained by the local villagers. This provided an opportunity to conduct a baseline survey, transitional surveys and evaluation surveys although the evaluation surveys were very limited because the hydropower had been operated and used by the villagers for only a few months.

- The hydropower component demonstrated very clearly that village participation can be successfully utilized in rural development projects.

- The hydropower component has not yet completely demonstrated the economic feasibility of this source of renewable energy because the government agency has provided free of charge all of the materials and hardware which are unavailable in the villages being served.

- There is a need for basic designs of micro-hydro plants and systems to be developed specifically for micro-hydro which are suited to the PARED technique so that there can be even greater involvement of the villagers, and so that micro-hydro plants and systems can be set up in the future without such heavy input from the governmental agency, especially with regard to the input of materials and hardware from outside. In other words, such projects can and must be made economically feasible to the villagers (who should pay all costs) at some point in the near future.

Recommendations

In investigating the implementation of the four micro-hydro power projects mentioned above, the following recommendations can be made:

- All the data necessary for the project design and planning should be carefully collected and recorded prior to the approval for the implementation of the project. The collection data should include:

  - Topographic map of the project area in a scale suitable for showing the sites for a weir and a powerhouse as well as the location of the villages that will receive the electricity generated from the project.

  - Detailed profile along the routes of the headrace and the penstock.

- Geologic structures at the weir site, the routes of the headrace and the penstock, as well as the site for the powerhouse.
- Socio-economic structure of the nearby villages, emphasizing the requirement of electricity for productive use.
- Hydrological data of the stream where the weir will be constructed.

• With respect to the hydrological study, a relavant method should be adopted in order to obtain as reliable data as possible. More field observation and data collection should be conducted to obtain the most suitable value of the design discharge. Detailed investigation of hydrological characteristics of the region with consideration of several potantial sites for micro-hydro power development should be conducted by the responsible agency.

• Since most of the potential sites for micro-hydro power development are located in a remote area where the accessibility is rather poor, operation and maintenance problems should be carefully considered in the design stage.

• The implementation schedule should take into consideration the time period needed for each task, including the purchase and delivery of construction materials, and equipment, the available manpower, the nature of the project area, and project features.

• Villagers' participation should be maintained since valuable indirect benefits result. In addition, some training program should be offered for those staff who are responsible for projects with this kind of work organization.

• A permanent unit in the NEA should be established for a rapid and systematic expansion of the micro-hydro program in the remote areas of Thailand which are sufficiently far removed from the national electric grid that it will be several years, at the earliest, before the grid reaches them.

• Careful study should be given to simpler and less expensive designs of all the components for micro-hydro projects in the future in order to reduce still further the overall cost of each project.

• Detailed study, with the villagers, should be given to ways for the villagers to pay more and more of the total costs of a micro-hydro power project--including the materials and the mechanical and electrical equipment brought in from outside.

• Greater care should be given to utilizing the participation of the villagers for every step of project development all the way from situation assessment and problem identification to operation and maintenance, monitoring and evaluation.

• The staff and program for the development of micro-hydro projects should be a part of, and be very closely tied and linked to, each of the nearby Regional Energy Centers.

NOTE: For the report in its entirety see, "Development of Kam Pong, Mae Ton Luang, Hui Pui, and Bo Kaeo Micro-Hydropower Projects", Published by the National Energy Administration/USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Powerhouse of Kam Pong Project

Weir at the Kam Pong Project

Previous Page Blank

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VILLAGE WOODLOT

Realizing that the rate of forest degradation in Thailand is alarmingly high (approximately 333,000 hectares per year since 1945), the Fifth National Economic and Social Development Plan focused on the problem of deforestation as one of the priority areas in the development of alternative energy resources. The purpose of the Village Woodlot Component was to demonstrate and study the techniques of planting fuelwood crops so that there would be a sustained source of fuelwood production for villagers in the Northeast, where consumption levels are the highest according to a 1970 estimate. The Woodlot Project was carried out by the Royal Forest Department (RFD) in coordination with the National Energy Administration (NEA) under the support and supervision of USAID. The Village Woodlot Component was comprised of five sub-components, name: Silviculture, Economics, Land Use, Sociology, and Utilization.

The project was carried out in seven provinces in the Northeast (Kalasin, Khon Kaen, Maha Sarakham, Roi-et, Si Saket, Surin, and Yasothon).

The overall purpose and objectives of the Village Woodlot Component were successfully achieved. The goal of the project was to develop greater institutional capability in the culture of plants for fuel and to support those social functions which foster the maintenance and improvement of fuel crops and of a wood resource base. The project was to establish the criteria for land selection for woodlot development; to analyze the social and economic factors of the village which promote the success of village woodlots; to determine the form of woodlots under the provision of land use, silviculture system and management; and to establish demonstration woodlots on the selected land.

Specific project objectives were to provide a sustained supply of wood fuel for both woodlot owners and non-woodlot owners; to lessen the pressure resulting from the cutting of trees in the natural forests and illicit cutting of trees on public lands in general; to create employment opportunities and increase income for rural families; to develop techniques to be used as an important first step towards a countrywide scheme; and to stimulate interest in tree farming by demonstrating the benefits derived from such development.

Given the magnitude of the resource degradation issue -- as well as the increasing pressure on available wood fuels -- this component made a major contribution towards the long-term need for effective resource management. It directly benefited the development of the rural areas both from the socio-economic and environmental points of view and, in particular, can increase the per capita income of the rural populace. In addition, the results of the Village Woodlot Project are vital to the continued resource needs of other components in the continuation of the overall project such as gasification and the production of charcoal as a sustained source of raw material.

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The Village Woodlot Component consisted of two overlapping phases. The pre-demonstration effort was the first phase and consisted of surveys, data collection, data analysis, and receiving approval for use of public lands. The second phase began with a concurrent evaluation and plan for implementation. The scope of work for implementing the Village Woodlot Project includes: project site preparation, establishment of the Project Center, survey and analysis of the necessary data for the project, establishment of woodlots, and personnel in-service training -- study tours or observation tours abroad to RFD personnel as part of the training component.

Sub-component Descriptions

Silviculture

Relevant data were collected on soil characteristics, climate in the region, topography and other conditions necessary for the development of trees. Data on the growth of a number of tree species were collected and assessed for annual growth rate and durability. Selection of the most appropriate fast-growing tree species was made based on its potential for survival, its ability to resist floods and drought, as well as its ability to grow well in saline and infertile soil. The species chosen as a result of this investigation was *Eucalyptus camaldulensis* (commonly referred to as red gum, river gum, red river gum).

By the third year of the study, 4,300 rai of public land (86%), school land (7%), and monastic land (7%) had been planted with this species at 41 sites. The average survival rate was 83%. By project completion, 6,000 rai had been planted.

Economics

Sample field surveys on the socio-economic conditions necessary for woodlot development were undertaken in four provinces (Maha Sarakhom, Roi-et, Yasothon, and Si Saket) to study population and education level, land tenure, and economic activities (farm activities in terms of crop production and livestock production and non-farm activities).

The proportion of households surveyed in each village varied, but averaged 25% of the total number of households. Results showed that 38.7% of the surveyed households in 8 project villages had to purchase fuelwood for their own use which indicates that the fuelwood shortage is becoming a serious problem in this region.

Land Use

Fuelwood scarcity and local needs for fuelwood were criteria used in choosing the seven provinces as sites for pilot village woodlots. Forest laws and regulations were taken into account for site selection and for ease in the process of village woodlot establishment; therefore, three types of land (public land, monastery land and school land) were chosen in each province to set up the village woodlot trial plots. Public lands were con-

verted into village woodlots by planting *Eucalyptus camaldulensis* with a spacing of 2 x 4 m. To induce incentives, agroforestry was applied. Economic cash crops such as cassava, corn, groundnuts and tobacco were promoted to plant in the woodlots.

The three-year Village Woodlot Project showed that woodlots were successfully started on public land, school land, and monastic land.

Sociology

In its study of the potential for use of village woodlots in the Northeast, the Village Woodlot Project used an interdisciplinary approach; the sociological subcomponent studied attitudes and motives of the villagers towards accepting the project including conditions of the villagers in the project areas, attitudes towards the project, and motives of the villagers for accepting the project. It also studied the opinions of school teachers and Buddhist monks about the Village Woodlot Project, as well as general sociological conditions characterizing these two groups.

The results revealed the attitude of the villagers towards the project as well as the relationship between their attitude and their educational level, their age, and the size of their farm. There was an insignificant difference between the attitudes towards the project by male and female respondents. The majority of the villagers studied were positive towards the Village Woodlot Project.

In surveying the teachers and the Buddhists monks, the majority very strongly agreed with the project.

Utilization

The purpose of this subcomponent was to determine the utilization of *Eucalyptus camaldulensis* when the trees reached maturity for other purposes besides fuelwood and charcoal. Assuming the trees were five years old, the utilization subcomponent suggested the following uses for woodlot projects: fuelwood and charcoal burning, prefabricated wooden fences, stickwood furniture, log cabin walls, house posts and electric poles, agricultural tools, flooring, handicrafts, woodchips, and fuel for electric generators. To ensure durability of fresh-cut timber, seasoning and wood preservation is important for wood utilization; a training course should be set up at the woodlot locations where simple methods for seasoning and preserving could be taught.

Conclusions

Silviculture

- *Eucalyptus camaldulensis*, when compared to other native and exotic species of wood, was found to be a promising species to be planted for firewood in the infertile soil of dry sites of Northeastern Thailand.

- Most planting activities (including seedling production, planting site preparation and plantation tending) have been carried out by the Provincial Forest Offices.

- Planting of Project Village Woodlots was concentrated on public land rather than on land belonging to temples and schools.

- Trees grown using an agrforestry system grew faster than those grown as a forest farm, though some were overpruned in Maha Sarakham where soil fertility is relatively high and farmers needed the land for upland-crop planting.

- Early planting in combination with alternative chemical fertilizer/ manure application could stimulate height growth. Later fertilization resulted in dieback in summer.

- More conclusions cannot be drawn since the project duration was not long enough to see complete tree growth. The fuelwood rotation for *Eucalyptus camaldulensis* is approximately five years and project completion saw only a three year growth. Investigation on coppice regeneration was not possible.

Economics

- 38.7% of the households purchased fuelwood which indicates that the fuelwood shortage is becoming a serious problem in this region.

- The average charcoal consumption per capita per year for all four provinces was 1.55 cubic meters. The average fuelwood consumption per capita per year for all four provinces was 1.42 cubic meters.

- No cost-benefit analysis could be performed as the trees were too young to harvest, so no measurements of actual yield were able to be made.

- The investment cost for each rai of fast-growing trees is 1,128 baht.

- The average yield of rice production per rai is about 17.67 tang/ rai when combined with Eucalyptus trees.

- Other cash crops (namely peanuts, mungbeans, Chinese kale, Chinese cabbage, tomatoes and coriander) can be combined with Eucalyptis trees yielding per rai, 60, 50, 100, 200, 60, and 100 kilograms respectively.

Land Use

- The idle grazing public lands of 3,705 rai have been forested with the fast-growing tree species *Eucalyptus camaldulensis* with the spacing of 2 x 4 m. Agroforestry systems are being promoted. This public land forest plantation belongs to the sub-district council and is managed by this council under the supervision of the district forest officer. Allocation of the benefits will be decided by this sub-district council.

- The school land woodlots were established under the cooperation of the school students and teachers under the supervision of the district forest officer. The maintenance and management of these woodlots were conducted by the school authority led by the headmaster and the temple's rector under the supervision of the foresters. The ownership belongs to the school/college. The benefits will go directly to the school/college. Allocation of the benefits will be decided by the school/college board.

- The temple land woodlots were established by the temple under the supervision of the foresters. The ownership of the woodlots belongs to the temple concerned. The maintenance and further management will be conducted by the temple with the supervision of the foresters.

Sociology

- If sustained growth or viability of the local system is needed, then the village woodlot should be integrated into elements of the rural social structure of Thai society.

- The majority of the respondent villagers were males in the middle and full adult age groups with a Prathom 4 education.

- The majority of villagers studied had good attitudes towards the Village Woodlot Project.

- The majority of the villagers accepted the project because they were motivated primarily by need for ample fuelwood, wood for making charcoal, and wood for sale to increase their own income or that of communes.

- The majority of the school teachers were young adult males who were married.

- The majority of the teachers had received a vocational education. Most of the monks received a Prathom 4 education. The residential period in communities of the teachers ranged from 2 - 6½ years, while that of the monks in the Wat was three years.

- The majority of the teachers and the monks agreed very strongly with the Village Woodlot Project.

Utilization

- Because the trees were not full-grown, it was not possible to reach conclusions as to the effectiveness of the utilization.

Recommendations

Silviculture

- Even though *Eucalyptus camaldulensis* has been established as a fast-growing species, trials with other species should be established. If it is possible, monoculture should be replaced by multi-species planting.

- Schools, temples, military camps and communities should play greater roles in fuel planting in the future. Trees could be planted on school lands, in military camps and even along the roads. Provincial forest officers may act as supervisors, coordinators and seed and seedling providers.

- If the planting site is not suitable for an agroforestry system, then spacing should be narrower -- 1 x 1 square meter or 1 x 2 square meters. If this is done, then mechanical thinning can be done in the third year in order to turn management from an even-aged to an uneven-aged plantation.

- To overcome overpruning problems found at Maha Sarakham, agroforestry systems should be introduced. For instance, when tree canopies get closer in the third year resulting in unsuitability for cassava planting, grazing of livestock may be allowed. Thus, agro-silviculture is replaced by a sylvo-pastoral system in the third year of planting.

- For better growth and survival, trees should be planted as soon as the rainy season begins. A small amount of mixed fertilizers and/or manure may be applied at planting time. Late fertilization should be avoided.

- Duration of the project should be prolonged to up to five or six years since the planted trees cannot be harvested for firewood when they are three years old. Project extension may provide an opportunity to investigate appropriate silvicultural systems.

- The project should concentrate its future work on provenance trials as well as on the establishment of a seed orchard of *Eucalyptus camaldulensis*.

Economics

- The way to increase the productivity per unit of land is to implement agroforestry systems and to grow other crops along with the fast-growing trees.

- Reforestration using agroforestry systems should be employed in the regions facing fuelwood and farmland shortages.

- The project should continue so that the trees can be harvested and the final analyses made.

Land Use

- Meetings, interviews, and discussions with the local people are very important first steps in establishing village woodlots.

- Selection of village woodlot sites should concentrate on degraded or idle grazing land.

- Allocation and distribution of the products or benefits should be the decision and under the direction of the village or sub-district council.

- Cottage industries and commerical industries are urgently needed to support the utilization of small wood products from the woodlot plantations.

- Continuation or a follow-up program for this Village Woodlot Component is necessary.

Sociology

- It was recommended that each system in the rural social structure (extended family, bilateral kindred, neighbors and neighborhoods, cooperative labor exchange groups, junior-senior relationships, entourage, faction, class divisions, natural village settlements, administrative apparatus of the state and the wat) be addressed by forestry officials and agricultural extension workers.

- For example, one way would be to approach abbots in the Wat and encourage them to grow trees on Wat land, provide young trees free of charge to all poor peasants to grow on their own land, and motivate landless laborers to reside in self-help resettlement schemes and community forests (as part of an approach viewing class divisions as a social system).

- It is highly recommended that forestry officials at the provincial and district levels should work in cooperation with agricultural extension workers, community development workers, and rural people to integrate the village woodlot into every element of the social structure.

- An adult educational program should be promoted by the Ministry of Education in cooperation with the Royal Forest Department in the Village Woodlot Project areas to provide fundamental knowledge on village woodlots, agroforestry, rural environment, etc.

- The Royal Forest Department should expand this project to all parts of rural areas in the country.

- Under the conditions where the primary needs of the villagers are for fuelwood and wood for making charcoal for home use, public land in every village should be used to grow fast-growing trees.

- The district and provincial forestry officials should strictly follow the policy and objectives of the Village Woodlot Project originally set by the Royal Forest Department. In addition, the provincial

governor should inform all the villagers and the governmental officials concerned that all benefits from the village woodlot would belong to the local villages, not to the provincial council.

- Public relations dissemination of information on Village Woodlot Projects should continue over radio and TV at least once or twice a month. Simple reading materials should be printed and distributed.

- All school teachers and monks were willing to carry on this project in their schools and wats provided that the trees in full growth belonged to the school or wat. Hence, the government agencies concerned should inform the principals of the schools and the abbots of the wats that the wood will belong to the school or the wat.

- Evaluation of the strengths and weaknesses of project implementation should be performed every one or two years.

Utilization

- The biggest tree trunks which reach 15 cm could be selected to be used as house poles, log cabin walls, or electric posts for the village-- or could be sold.

- The biggest trees could be used for wood flooring such as parquet or mosaic. In this case, small-scale forest industries, including wood seasoning and preservation, should be established where the large-sized woodlot area is situated for additional village income.

- The smaller trees (under 15 cm) could be used to make wooden fences and stick wood furniture for village use and for sale.

- Branches and butt-ends of the trees left should be used for fuelwood and charcoal making production and benefit sharing should be organized by the village council.

- Gasifiers run by fuelwood should be introduced where there is a large-scale woodlot. The fuelwood gasifier could run a water pump, rice mill, or an electric generator. The work will provide benefits to all the villagers and will create a cooperative attitude in their minds.

- To achieve the project objectives and to complete its implementation, seminars (or training courses) should be established for training at least three levels of people -- the villagers, district officers and provincial officers -- on potential utilization of woodlot products.

NOTE: For the report in its entirety see, "The Village Woodlot: Its Implementation in Thailand", Published by the National Energy Administration/ USAID, under the Renewable Nonconventional Energy Project #493-0304, Bangkok, Thailand, 1984.

Villagers participate in planting seedlings
in the Village Woodlot Project.

Growing tapioca and Eucalyptus in Ampuhr Kosum Pisai, Sarakam.

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Chapter 3

DISSEMINATION, DIFFUSION AND ADOPTION

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Dissemination, Diffusion and Adoption of Rural Energy Technology

This Chapter summarizes a report by Dr. Amara Pongsapich on the Participatory Action Technique for Rural Energy Development (PARED). This approach to rural development is discussed here as the basis for designing and explaining a practical program for dissemination, diffusion, adoption and long-term use of the renewable energy technologies which have been developed in the past five years through the Renewable Nonconventional Energy Project. The practical program design described and explanined in this section of the report is based on the work of Dr. Pongsapich and on certain implicit assumptions, as follows:

1. The plan/design must be economically feasible and economically and conveniently more attractive than the alternate energy sources, including petroleum products and current wood sources.

2. The plan/design must involve the Regional Energy Centers (RECs) which are located throughout Thailand.

The PARED (participatory action for rural energy development) technique described herein must have available a minimum of two well trained people to work with the villagers. These are:

1. The Energy Development Officer (EDO) and

2. The Energy Development Engineer (EDE)

The Energy Development Officer (EDO)

The EDO must have special training and be very skilled in the fundamental and practical aspects of community development, group interaction, and a general knowledge of the various renewable energy technologies. He/she must be able to: assess the characteristics of a village, organize and conduct group meetings, assess and utilize the consensus of the meeting, guide the group to a decision that the group can strongly support and on which the members will act, know when he/she needs competent technical advice from the EDE, and follow up on all of the many steps described by Amara in order to see the project in a village through to completion and long term success. In order to obtain people with these skills and interests, it will be necessary to provide special training programs both in the classroom and in the field--which will require many months to complete. It is essential that the teachers in such a training program be well grounded in the fundamental principles involved, but also (and especially) have had extensive experience working and living in the rural villages of Thailand.

**This chapter was written by Dr. Maurice L. Albertson, Senior Technical Project Expert.*

The Energy Development Engineer (EDE)

The EDE must be carefully selected as an individual who has great empathy and respect for the villager and the important contribution he/she can make to the discussions and decision-making for the dissemination of renewable energy technology. For this purpose, the EDE must have special training--although not as extensive as the training for the EDO.

The Regional Energy Center (REC)

In order for this program of PARED to be most successful, it should operate through and out of the RECs as a base. Each REC should have at least one full time EDO and one EDE attached to it, and their method of operation should be as follows:

1. On the basis of the baseline surveys already conducted (or in the process of being conducted), the EDO should select one village which he/she thinks could be successful with the PARED program and could serve as a pilot project--and then he/she should proceed with the step by step process as described by Amara.

2. Once the DO has arrived at the point of needing more detailed technical advice than the DO can provide, he/she will call on the engineer to join the discussions in the village and help to bring the discussions to a satisfactory conclusion.

3. Once a plan has been developed which is satisfactory to all concerned, the other steps (described by Amara) should be followed, with the involvement of the EDE and the survey people where and when needed.

4. After a project is implemented, it is extremely important for the EDO and the EDE to monitor the project, at least once a week for the first month or two and then not less than once a month until the project has been operating as intended (without interruption and without difficulty) for at least 6 months--and then it should be monitored quarterly on a routine basis. Separate questionnaires should be made up (for the EDO and the EDE) which they will fill out for each visit.

5. In addition, the Survey Component should continue separately with its routine surveys (baseline, transitional, and evaluation) as originally planned and designed for this project. The personnel for the Survey Component should be separate and apart from the REC and not attached in any way. It is essential that a completely impartial survey be conducted without any possible conflict of interest and that the Survey results be reported directly to the Secretary General of the NEA or his officially designated representative.

6. The evaluation of the project should be conducted by the Survey Component, completely apart and separate from the REC and its staff. This should be a continuing activity of not less than once each year, and much more frequently for the first year after the project commences operation.

Program Expansion

As the EDO has time to search out another village to work with (using the PARED technique), he/she should do so. However, he/she should not get him/herself, or the EDE, spread so thin that the villagers become dissatisfied with his/her services--which could undermine the entire program.

Once there are one or more successful projects attached to an REC, representatives from other villages will come voluntarily to the REC asking questions and requesting help with their own energy problems.

This should soon provide so much demand for the services of the REC that additional EDOs (and eventually additional EDEs) will be needed on the permanent staff of the REC. As the program becomes better and better known and in greater demand, it will eventually become necessary to build additional REC's throughout the country--and to expand the facilities and services of all the RECs. This will be a process of evolution which will come naturally by popular demand from the villages. An immediate need for expansion is the addition of a Training Program within each REC.

Training Programs

The RECs will not be providing all of the services that are needed by Thailand unless and until a Training Program, with the necessary facilities and staff, is added at each REC. Eventually, for maximum success, the REC will need to require certain actions from each village as conditions before the REC will work with them on developing renewable energy programs. One requirement should be that the village will designate one or more energy representatives who will attend regularly (and without fail) an energy meeting each week: for training on both theoretical and practical aspects of energy technology and for exchanging experiences with representatives from other villages--so that they can provide the very best leadership possible in planning, building, operating, and servicing energy technology in his/her village.

The staff for the training program at each REC will no doubt need to involve the EDO and the EDE who are working in the villages, but the Training Program must be under the leadership, guidance, and planning of a Training Officer (TO) who has him/herself received training on planning and operating educational and training activites.

Cooperation with Other Development Agencies

In order for the rural energy development program to be most successful, it will be necessary to work jointly with other development agencies in Thailand so as to create a balanced program of rural development. The energy sector alone cannot stimulate or create complete and balanced development. A balanced program must include other sectors such as: health, agriculture, education, industry, and public works, see Albertson 1983. Most of these sectors are being promoted in the rural villages of Thailand through various agencies of the RTG and by non-governmental organizations(NGOs) which are working in Thailand.

As rapidly as possible, the NEA should initiate cooperative and joint activities with these other agencies so that a truly balanced program of development is made available to each village and its people throughout Thailand. Furthermore, the RECs should be expanded in size, facilities, staff, and program; and all of this should be made available to the other cooperating agencies for joint programs--thereby making each REC a truly complete and successful Rural Development Center (RDC).

Such a program will no doubt take several years to accomplish, but discussion,cooperative and joint activities should be initiated immediately.

Importance of Participation

The importance of "participation" in the success of the dissemination and adoption program cannot be over stressed. Participation is so extremely important that it can be stated without question that the dissemination program cannot possibly fully succeed without it.

There are many advantages to the participation technique:

1. In the long run, it is the most economical approach. No other system can involve so few outside people and so little input of outside physical resources, such as supplies, materials, and equipment.

2. It is an intensive educational (experiental learning) process for all who participate, which leads to self-reliance on the part of both the villager and the village, as follows:

a) Each and every villager who participates learns the process of assessing the situation and identifying the problems surrounding and confronting him/her as an individual and also the entire village as a whole.

b) He/she also learns how to plan and design a solution to his/her problems and then to build or carry out the solution.

c) In this process, the villager has also learned how to operate and maintain the facilities and/or program which provide the solution.

d) Especially important, the villager acquires a confidence and self-respect which will provide incentive and enthusiasm for solving other problems with a minimum of outside help.

e) The EDO and EDE obtain very important information about the individuals and the villages, in which they work, that is not obtained by the Survey Component and the statistical analysis of their data. The questionnaires which they fill out should be designed to elicit this unique information and make it a part of the permanent record.

3. In summary, the PARED technique builds a human resource base that is absolutely essential for the rapid development of the rural areas of Thailand, and for the complete and more broadly expanded development of the entire nation--including the urban and large industry sectors. This is the 80% of Thailand's population which has been virtually untouched by the large development programs of the past 30 years.

Conclusions

for

Participatory Action for Rural Energy Development (PARED)

1. The ideas of self-reliance and participation have been highly successful in many situations in a number of countries, especially when it is necessary to operate on a shoe-string basis, and they have a great potential for reducing the consumption of wood and providing energy for other activities in the rural areas of Thailand.

2. The participation technique in so extremely important that it can be stated without question that the dissemination program cannot possibly fully succeed without it.

3. Participatory action has the great advantage of being an experiential learning approach which involves the villager in all phases of discussion and decision-making--all the way from the earliest stages of assessing his situation and defining his problem (situation analysis and problem identification), to planning and designing a solution, to the final construction and O+M of the solution to the problem.

4. The concept of the PARED technique for diffusion of technology is a bottom-up approach which is far superior to the old, and highly unsuccessful, concept of "the change agents and the adopters" which uses a top-down approach to development.

5. The PARED technique requires a minimum of outside input and the experiential learning produces a maximum degree of self-reliance, self-confidence, self-satisfaction, and enthusiasm on the part of the villager.

6. The PARED technique provides the villager with the tools and the incentive to assess and solve other problems which are confronting him.

7. The PARED technique is a system for carefully monitoring project activities with feed-back mechanisms which provide justification and flexibility for altering the assessment, implementation, and operation of new and old projects as new information makes such changes seem appropriate.

8. The PARED technique involves the villagers in identifying the problem and potential solutions. It also increases awareness and committment among villagers, uses a dialectic process, builds local capabilities for solving social problems, and allows the villagers to gain "the power of knowledge".

9. The PARED technique assures that the information obtained will more accurately reflect the local perceptions, habits, codes, mores,preferences, and real needs.

10. The PARED technique assumes that the villagers have knowledge that is equally important to that of the EDO in defining and implementing options that will improve the quality of their lives.

11. The PARED technique allows for developing dynamic responses in a dynamic environment and gives the villagers new tools to continue to make these decisions after outside expertise and guidance have gone.

12. A document is needed which will explain the alternative renewable energy technologies that can be distributed to the villagers to give them a general understanding of their energy options and how to assess which alternatives will be most applicable and useful to them. This document will be of extreme value to the EDO and the EDE.

13. It is important to realize that the Survey Component must continue with its activities because these survey activities are assential to successful plans and designs for dissemination programs, and the data collected are different from those data obtained by the EDO and EDE.

14. There is a need for a contract to be developed and signed between the REC and the villagers which clearly spells out the obligations and schedule for all concerned.

15. There is a need for each village to agree (as a part of the contract) to send a representative for regular training at the REC on the details of practical use of various renewable energy technologies.

Recommendations

for

Participatory Action for Rural Energy Development (PARED)

1. That NEA make a major and firm decision, set up a basic policy, develop specific and detailed plans, and provide the necessary budget to initiate the PARED program for dissemination of renewable energy technology in the rural areas of Thailand.

2. That the assigned activities of the RECs be expanded to include an aggressive program of working with the villagers as described in this report.

3. That potential EDOs and EDEs be identified, employed, trained and permanently stationed at each of the RECs.

4. That the EDOs and EDEs be put through an extensive and intensive training program to prepare them to be most successful in their work at the RECs and in the villages.

5. That a contract be required for the establishment of a cooperative program between the REC and each village which it helps, and that this contract include the provision that the village must provide one or more people for regular training programs at the REC.

6. That the entire NEA/REC program be built on the concept of self-reliance and participation with a minimum of outside support from the RTG. The supplies, materials, and equipment provided by the RTG should be held to an absolute minimum. This help should consist only of those items which are absolutely necessary for success of the project. As many of these items as possible should be provided by the village--especially that which can come from local natural and human resources without cost to the RTG.

7. That the entire PARED program be designed to optimize the experential learning process for all people concerned with a view to building a human resource base which will have value nationwide--and that it be a program which assumes the villager has more to offer than the EDO in assessing, defining, and solving his energy problems.

8. That the NEA prepare one or more documents which explain the alternative renewable energy technologies and how to choose, develop, and use them for maximum advantage.

9. That the Survey Component continue its various surveys with special emphasis on the evaluation survey on a continuing bases for all REC projects. These data should be fed to appropriate NEA officials as feedback for improving the future planning and operation of REC activities and projects.

Chapter 4

General Findings, Conclusions and Recommendations

from the Village Survey Component

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GENERAL FINDINGS, CONCLUSIONS AND RECOMMENDATIONS FROM THE VILLAGE SURVEY COMPONENT

Being a developing country, Thailand is fortunate not to have been fully dependent on petroleum, especially in the rural areas. However, Surapong Chirarattananon (1983) states the following:

> Efforts of the first two development plans, spanning 1962-73, concentrated on the construction of economic infrastructures. Typically, energy resources were imported without constraint, so that over three times as much energy was consumed in 1972 as in 1962. Moreover, the early pattern of petroleum fuel consumption as well as the composition of the refinery output contributed to price differentials distinctly favoring diesel fuel, greatly augmented its use.
>
> The energy crisis in 1973-74 erupted during the middle of the Third Plan, causing serious repercussions.....
>
> (But) in spite of the disturbance caused by the energy crisis, agriculture continued to grow at an average rate of 4.8 percent per year during the Fourth Plan (1977-1981) -- a slightly slower rate than the 5.2 percent per year during the previous 15 years. That continued growth in agriculture hinged on the 4 percent per year expansion of land under cultivation.

However, the growth in agriculture has been independent of energy consumption, conventional as well as nonconventional. Again Surapong states,

> Commercial energy in rural areas, where over 72 percent of the population lives, accounts for only 13.5 percent of the total commercial energy used, even including the 4.8 percent used in agriculture. Commercial energy consumption is highly concentrated in the highly developed, heavily concentrated industrial, and heavily populated urban areas.

The reason that commercial energy is heavily concentrated in urban areas naturally reflects economic reality, since the energy requirements of manufacturing industries are much greater than those of agriculture. Urban areas always have priority over rural areas. Electrification as well as sales of other commercial energy products are aimed at the urban areas and only when demand in the urban areas is saturated will the supply flow to rural areas. There is a general feeling in many quarters that rural development may be enhanced by the introduction of electricity, though no studies appear to have been carried out so far to establish the nature and extent of such a relationship.

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* *This chapter was written by Dr. Amara Pongsapich and is based upon information she obtained in the course of the work with the Village Survey Component.*

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When electrification is introduced in rural areas, most normal villagers cannot afford to use it for purposes other than lighting. Exceptions are seen in households where there are home industries and in households where water pumps are used to irrigate vegetable gardens. Use of refrigerators, televisions, and rice cookers is seen only in households with incomes higher than average. The 4.8% use of electricity for agriculture(mentioned by Surapong in chapter 1) is mostly subsidized by the government budget through the National Energy Administration (NEA). The NEA has several pumping projects where electricity is used. In 1983, the NEA reported a 20 million baht budget for subsidizing this project each year and villagers paid approximately 8 million baht.

One then turns to examine noncommercial fuel as a possibility to replace commercial fuel both for household consumption and production. For household lighting, the use of micro-hydro technology and community biogas for electrification is technically possible but not cost-effective due to the high investment cost for construction and the limited production. In all of the projects implemented, energy allowance for each household is only 40-60 watts or two light bulbs and one outlet. However, if it can be installed cheaply, then community biogas and micro-hydropower can become the ideal form of nonconventional energy for use in remote areas where the central grid does not reach. Since most villagers cannot afford to use electric appliances other than lighting, the amount of electricity generated would be sufficient. Remote areas are emphasized here because it is the interest and goal of the Thai government to bring electricity to all communities within the country for developmental as well as national security reasons. The extension of the central grid to remote areas can be avoided if nonconventional energy can be used.

The historical development of cooking fuel in Thailand may be traced from fuel wood and/or agricultural waste, to charcoal, and then LPG. In the past, fuel wood and charcoal were used because wood was available, but LPG was quite readily accepted after the first year of introduction in urban areas. This is because supply was easily available and accessible and the price was subsidized. The container deposit is the most expensive part of the purchase. In the future, if new forms of energy are to substitute for LPG or fuel wood and charcoal, then price and accessibility will be the most important factors influencing cooking habits and fuel use for most of the households. At present there is no noncommercial fuel which has high potential to be used as cooking fuel in the near future.

It is now realized by all that a fuel substitute for oil is needed. If the natural gas supply in the Gulf of Siam is large enough, LPG will certainly be the answer. Even with the revised, lower estimates, it appears that once the gas separation plants are in operation, supply will be sufficient. Engines and generators may be modified to use LPG instead of benzine. In the area of agriculture if LPG can be used for water pumps, tractors, and other mechanized equipment, reliance on commercial petroleum products will then be reduced. Similarly, if LPG can be used to run generators and other engines or equipment in industries such as transportation, a new phase in energy technology may be underway. Unfortunately the last report on the amount of natural gas available is only approximately 25% of the projected amount, and other alternative fuels may have to be proposed.

Photovoltaic cells, which are relatively expensive, are reported to be commercially viable if produced on a large scale. If solar receptors can be used to produce energy to operate other machines, solar energy certainly has a bright future in terms of a substitute for petroleum energy. Solar energy for refrigerators, water heaters, and water distillers has been developed and is being improved. However, in rural areas these appliances are not yet in demand and health centers are the only units needing these appliances. On the other hand, if solar cells can be used to operate a water pump at reasonable cost, then acceptance as an energy source will be very likely.

Similarly, the use of windmills for irrigation is possible but not viable. Three windmills are required to irrigate 96,000 square meters of land in a village in Yala Province, Southern Thailand. The use of windmills as a source of energy is likely only in cases where they are given free of charge. Only high income people invest in windmills as an energy source. Maintenance is also another important factor inhibiting wider acceptance of this form of energy technology.

Micro-hydropower as an energy source in Thailand should be considered very carefully since investment cost is very high in terms of energy produced, and high subsidies may be needed. Furthermore, micro-hydro should be considered as a source of energy supply in remote areas only. In other areas, electrification is certainly cheaper to invest in both at the government and private commercial levels. In Fang District, Chiang Mai Province, micro-hydro was introduced to generate electricity to supply a small cannery. Now the electricity generated is incorporated into the central grid system of EGAT. It is also reported that at present the amount of electricity used by the cannery is more than the amount generated by the micro-hydro system located in the village.

The use of wood for fuel wood and charcoal is the most important energy source in Thailand. The introduction of community woodlot projects in Northeast Thailand has proved to be successful in the eyes of most foresters. Fast growing trees are now very much accepted because

of the immediate impact seen after 1-2 years. In the areas where soil quality is good, the growth of these trees is already attracting the attention of the villagers. Now, new provincial projects promoting woodlots both for reforestation and for commercial use are seen more and more. Expansion of woodlot projects in Thailand will be quite rapid in the next five years. The coutrywide network of the Department of Forestry makes promotion of woodlot programs feasible. If seedlings are made available, nurseries may be set up to propagate and redistribute the young plants, and the spread of fast growing trees will be immediate. In addition, fast growing trees are now being planted voluntarily in the paddy fields and house grounds. The future of the woodlot programs in Thailand looks very bright.

Thailand still has quite a way to go in terms of nonconventional energy. The same is probably true in most other countries. However, nonconventional energy use on a small scale, with local management making each community self-reliant in energy, should be considered seriously. Social benefits gained from making the communities self-reliant in energy would make the project attractive and worth the investigative effort. It is only in this way that social benefit can be imputed and the investment made cost-effective.

The concepts of participation and self-reliance used in this project are very appropriate and fit well with promotion of energy development. Since the ultimate goal of this project is to avoid being dependent on oil and petroleum products, development of renewable nonconventional energy should therefore make the community self-reliant in energy supply in participatory, communal effort.

Chapter 5

CONCLUSIONS

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CONCLUSIONS

This Chapter on Conclusions has been organized to present Project conclusions by component in three general categories. Conclusions cover:

- Findings
- Accomplishments
- Significance

In addition, Overall Project conclusions are presented at the end of this Chapter.

A. CONCLUSIONS FROM THE PROJECT COMPONENTS

VILLAGE SURVEY

Findings

The Village Survey Component of the Project was organized to record locality-specific, socio-economic data from representative villages in Thailand. Surveys were conducted and data were collected before and during implementation of specific energy-related technologies (including those of Charcoal Production, Biogas, Stoves, Woodlots, Micro-Hydro and Water Lifting). The baseline survey included a study of secondary data, design of the sampling framework, and preliminary site visits. Villages were selected based on regional location and ecological conditions. Activities examined included cooking, industry, agriculture, fuels, water supply and markets. The transition survey explored the problems associated with introducing the technology into the village. Evaluation surveys, as originally planned, have not yet been carried out due to time limitations. They were planned to measure the changes resulting from the operation of the new technology and its acceptance.

Accomplishments

- 1900 households in 50 villages in 10 provinces were interviewed for baseline data;
- Qualitative data as well as quantitative data were collected;
- Surveyors gained experience from the computer analysis of the data and from evaluation of the questionnaires;
- Survey information was fed to project components for planning purposes;
- Survey information was used in strengthening the Energy Master Plan Submodels and the Rural Energy Models.

Significance

The surveys provide systematic records of community characteristics before and during implementation of technologies, and provide information regarding renewable energy resources in specific provinces of Thailand. These records are also valuable for identifying strengths and weaknesses of projects leading toward the success or the failure of a specific technology.

SOLAR AND WIND ENERGY ASSESSMENT

Findings

In order to assess solar and wind energy for Thailand existing data were analyzed and additional solar radiation and wind measurements were taken. Solar radiation monitoring stations and wind monitoring stations were established. At these stations, observed solar radiation and wind were transformed into electrical signals and fed into dataloggers for real-time data processing. The processed data were then automatically recorded on magnetic tape cassettes for further analysis. These efforts form a solid base for further, future data analysis.

Accomplishments

- The Center for Solar and Wind Calibration--for continual measurement, calibration and maintenance of radiation and wind instruments was established.
- Relevant meteorological data generating a useful set of numerical values for solar and wind energy which will serve as a frame of reference for calculation of potential energy was evaluated.
- 6 solar radiation monitoring stations were established.
- 10 wind monitoring stations were established.
- The Center calibrated the existing solar and wind radiation of many agencies.
- The Project established new measurement, collection and data evaluation processes.

Significance

The solar and wind energy assessment is considered to be the most important step to be taken before systematic harvesting of both types of energy can be done. This assessment provides the foundation for sound technical, economic, and social decisions regarding the future use of solar and wind energy.

THE NATIONAL ENERGY INFORMATION CENTER

Findings

The National Energy Information Center (NEIC) has been established at the NEA to collect, organize and disseminate domestic, regional and international energy information to be used by energy economists, planners, and decision-makers. Revision of the sources of energy information was initiated and the existing library facilities were reorganized to create a modern information center supplied with modern equipment, including a computer system. The data at the NEIC supports the Energy Master Plan and serves further as the energy information referral center for information exchanges among other agencies.

Accomplishments

- Renovation of the NEA library and existing library facilities;
- Establishment of the computer center;
- Development of data processing activities and building data bases;
- Issuance of publications to users in English and in Thai;
- Training of local staff on information systems in Bangkok, on Hewlett/Packard software in Singapore, and MINISIS software training.

Significance

The NEIC can now disseminate information on the development of renwable and indigenous energy sources as well as create an awareness of the importance of energy resources, their consumption and environmental considerations. By automating information the NEIC can play a leading role in collecting and disseminating information for use in the energy planning process on the national scale.

ENERGY MASTER PLAN SUPPORT

Findings

The Energy Master Plan (EMP) model was improved by constructing and improving the submodels of the Energy Master Plan Model and Rural Energy Models. The models and submodels were: the Rural Energy Use Model, the Transportation submodel, the Electricity submodel, the Textile submodel, the Paper Industry submodel and the Urban Household and its Tertiary submodel, the Household Energy model and the Rural Community Development Model. Using linear programming techniques, links among models and submodels were strengthened so that the submodels could be run in conjunction with but also separately and independently from the EMP model. Sensitivity analyses on structural and nonstructural answers to "What...if" kinds of questions were simulated for a number of real base-cases and hypothetical projections.

Accomplishments

- All submodels of the EMP were successfully developed;
- All submodels were successfully run except for the Urban Household and tertiary submodel;
- All models operate as sectoral or macro-planning models.
- The Rural Energy Models (HEM and RCDM) were successfully developed and tested;
- Models can be used for planning and/or assessment of existing energy situations or projected ones;
- Produced an expanded version of the Energy Master Plan;
- Developed supply and demand submodels;
- 5-year sectoral development project plans were established for a number of base-case villages.

Significance

The new models and submodels provide NEA with ability for sectoral as well as macro-energy planning, will assist the NEA in developing more effective rural energy development programs and will significantly aid in the acceleration of rural development (a prime objective of Thailand's Fifth Five Year Development Plan).

REGIONAL ENERGY CENTERS

Findings

The Regional Energy Center Project localizes government activities in energy development, dissemination and promotion. Four Regional Energy Centers were established, buildings were constructed, energy equipment was procured and installed, personnel were hired, and vehicles were acquired. The Regional Energy Centers are: a) fulfilling the basic energy needs of rural areas by bringing in energy technology and energy equipment, b) demonstrating the use and usefulness of renewable conconventional energy systems and equipment, c) assisting the rural community in energy implementation, d) training government officials, and e) collecting basic community data.

Accomplishments

- 4 Regional Energy Centers (RECs) have been established--at Mahasarakhon, Pitsanulok, Ratchaburi and Nakhonsrithammarat Provinces;

- Each REC has the following energy technologies: windmill, solar hot water, solar dryer, solar distillary, photovoltaic cell, biogas digester, biomass gasifiers, efficient cooking stove laboratory and improved charcoal kilns and are equipped with workshop tools, field tools, laboratory and monitoring equipment, and training and visual aid equipment;

- 100 rai of fast-growing trees and oil seed trees have been planted in the Centers and 50,000 plants have been distributed to village plantations;

- Sociological and village surveys have been conducted;

- Extensive training and education programs were carried out through the use of radio, TV and printed materials.

Significance

The Regional Energy Centers have proven to be an important link between the rural villagers and government officials. This link provides information on rural energy needs and also on dissemination of energy technologies to the rural areas.

BIOMASS GASIFICATION

Findings

The Biomass Gasification Component developed a number of gasification systems and, based on testing and/or implementation programs, recommended a set of proposals for the development and/or dissemination of biomass gasification technology in Thailand. The main conclusions of the study indicate a reasonable amount of confidence in the prospect of disseminating these units; that wood gasifiers need be technically optimized before implementation; that fixed bed crop residue gasification show prospects of becoming a future gasifer raw material; and that fluidized bed gasifiers have been shown to be able to gasify rice husk.

Accomplishments

- 12 gasification units were constructed and tested ranging in size from micro-gasifiers producing 500 Watts of electricity to pilot-scale fluidized bed systems;
- The small-scale charcoal gasifiers proved to be very convenient for rural use;
- The development of reliable wood gasifiers was undertaken and novel methods of gasifying shredded crop residues were evaluated to minimize tar formation;
- Fluidized bed gasifiers were developed to gasify rice husk.

Significance

With its abundant vegetation and crop and animal residues, Thailand is in a good position to use producer gasification systems. This Biomass Gasification Component has now become a research and development unit in Bioenergy at Chulalongkorn University. Future research and development will focus on gasification.

SOLAR THERMAL PROCESSES

Findings

The Solar Thermal Processes Component developed solar thermal equipment suitable for different applications in rural and urban areas of Thailand. Three types of solar thermal processes, namely solar distillation, solar refrigeration, and solar drying, were investigated.

The Solar Distillation Project tested various types of solar stills for rural and urban use to develop improved models. The solar still was developed with an aluminum lining and charcoal chips as the absorbing material. It yielded good quality distilled water.

The Solar Refrigeration Project designed, constructed and tested a solar ice maker with a capacity to produce 15 kg of ice per day. An ammonia-water absorption refrigeration was selected. Based on the test model, a second ice maker designed for ease of operation has been developed and is being tested.

The Natural Convection Cabinet Drying Project introduced the technology of solar drying to villagers , developing a simple, inexpensive solar cabinet dryer with a separate air heater that could be used for small-to-medium-scale drying of food and agricultural products. Users who dried a medium amount of produce were interested in the dryer which produced dry, hygenic bananas, beef, coconut, and fish.

The Forced Convection Hut Drying Project designed, developed, constructed and tested a low-cost solar air heater and grain dryer. One ton of paddy was dried by solar energy and ambient air. The moisture content was reduced from 22% to 16% dry basis in about one day. A mathematical model was developed that can predict the efficiency of the solar collector accurately at low inlet air temperatures.

The Solar Tobacco Curing Project was undertaken to develop a solar-rock-bed system for flue-curing tobacco in Thailand. An experimental tobacco curing barn, using solar heated drying air via a flat plate solar collector, was constructed. Experiments in curing fresh tobacco leaves were carried out: four tests using only LPG as fuel, then three solar-assisted test runs. It was found that the solar-assisted test runs yielded an average fuel savings of about 28% over LPG use.

Accomplishments

- 3 types of solar stills (both vertical and horizontal) were developed and tested;
- 20 units of improved solar stills were fabricated and put into field operation in rural areas;
- A test model of a solar ice maker with a capacity of 15 kg of ice per day was designed, constructed and tested. A second improved model is under construction;
- An efficient solar air heater was developed and incorporated into a free convection cabinet dryer for agricultural products. Field tests were conducted;
- Paddy drying time was successfully reduced by the design and construction of a low-cost fixed-bed dryer using hot air produced from a solar air heater and circulated by a blower;
- The construction of a tobacco curing barn utilizing solar drying techniques to cure tobacco reduced fuel costs nearly 30% over LPG.

Significance

Results indicate that the use of solar energy is technically and economically feasible as an alternative energy source in Thailand. Specifically, low-cost solar stills can provide hygenic water at a cheaper cost for rural and urban use; spoiled wet grain during the rainy season can be ameliorated with the use of the solar paddy dryer.

The solar refrigeration research program has served to create additional research activities within KMITT and has resulted in an extensive training program for individuals involved in solar refrigeration research.

PYROLYSIS OF RICE HUSKS

Findings

The Pyrolysis of Rice Husks Component was carried out to investigate the techno-economic feasibility of rice husk pyrolysis and its application to rice mills. During its technological development phase, a pilot plant capable of converting one ton of rice husk per day into combustible char, gas and oil was constructed. The study investigated engineering design, cost data, and utilization of by-products.

Subsequently, two demonstration plants were constructed at Sara Buri and Pichit Provinces to further investigate the techno-economic viability of rice husk pyrolysis. It was determined that the technology could and should be applied to rice mills operating with diesel engines with rice husk production of at least one ton per day. These mills could profit by using the gas produced and from selling the char and oil products, useful as a cooking fuel and a liquified fuel when mixed with fuel oil.

Accomplishments

- A pilot plant capable of converting one ton of rice husk per day into combustible char, gas and oil was constructed and evaluated.
- 2 demonstration plants at Sara Buri and Pichit Provinces were built to further investigate their techno-economic viability.
- It was determined that the unit could be paid off with a period of 2.2 years with a 38% internal rate of return.
- Rice husk pyrolysis technology could and should be applied to rice mills operating with diesel engines and producing not less than one ton of rice husk per day.
- Data on 158 rice mills and 1511 surrounding households were collected and analyzed.

Significance

Because of the enormous supply of rice husk available in Thailand, pyrolysis technology has the potential to turn what has been a waste and environmental nuisance into a valuable renewable energy resource. By using the gas and selling the char and oil produced by rice husk pyrolysis, owners of rice mills can make a substantial profit and pay off their investment in two years.

INDUSTRIAL BIOGAS

Findings

Industrial wastewaters were analyzed and treated to produce gas using the anaerobic digestion processes. The results of the preliminary analysis and laboratory scale experiment indicate that the anaerobic technique of treating industrial wastewaters is possible, but not yet economical. Tapioca waste was found to be the most suitable waste for generating biogas in terms of quantity of gas produced and quality of methane gas.

Accomplishments

- 5 types of industrial wastewaters were analyzed for gas production and gas composition: namely, tapioca waste, noodle waste, sodium monoglutamate waste, canning food waste, and dairy waste;
- Data was collected on two types of anaerobic digestion processes -- the anaerobic filter and anaerobic contact processes.
- A 50 cubic meter digester was designed for the demonstration plant.

Significance

Although the results of the research indicate that the treatment of industrial wastewaters by these processes is not economically feasible at this time, they indicate that the technique itself is possible. This research adds to the knowledge of the NEA officials in their search for new ways to treat Thailand's industrial wastewaters as an energy source.

The NEA will continue to explore the use of high organic load factory wastewaters by importing cost-effective anaerobic systems.

STOVE IMPROVEMENT

Findings

The Stove Improvement Project was designed to research and develop highly efficient biomass household cooking stoves of three generic types: charcoal, wood (with and without chimney) and rice husk or agri-residue (with and without chimeny). Activities undertaken included collection and selection of commercial stoves, stove development to yield better design, prototype testing, improved stove production and fabrication, and the promotion of the improved final models. The performance in terms of heat utilization efficiency for each type of stove as compared with the existing or commercial models was increased significantly. Reception of the improved stoves by villagers was excellent. They preferred the charcoal bucket and wood stove without chimney.

Accomplishments

- A cooking stove testing laboratory at the Forest Products Research Division was established and equipped with invaluable, basic test instruments and facilities (including a microcomputer system);

- The performance in terms of heat utilization efficiency for each type of stove as compared with the average, existing or commercial models was:

Stove Type	% Increase in Efficiency
Charcoal bucket	26
Wood with chimney	58
Wood without chimney	37
Rice Husk with chimney	100
Rice Husk without chimney	19

- In addition to the heat utilization increase, certain stove features were also improved--particularly the stove rim design to accommodate various sizes of pots and pans, fire-resistant characteristics of pottery liners for charcoal and wood stoves, and increase of service life;

- Good quality clay material suitable for stove manufacturing has been identified and a production technique has been developed for small-scale and home industries;

- A 100-ton hydraulic automatic press machine for forming a precision clay bucket has been designed;

- 9 improved stove promotion and training programs have been carried out among villagers at various places around the country.

Significance

Since 89% f six million rural families either use charcoal, wood bucket, or three-rock stoves, the potential for replacing poor performance stoves with the two improved models is very high. With the use of the improved stoves, a decrease in national, overall fuel wood consumption (and hence, an indirect decrease in the rate of deforestation) can be expected.

IMPROVED CHARCOAL PRODUCTION

Findings

The Charcoal Research Center has been successfully established to deal with charcoal improvement for rural development. The Center and the RFD laboratory are well provided with scientific equipment to cope with present and future research, development, and promotional training.

A nationwide charcoal survey was completed and results were published. The survey revealed that Thailand's charcoal consumption is as high as three million metric tons annually. The project evaluated thirteen charcoaling methods using eighteen kilns of various sizes and twelve models. Test results indicated that permanent charcoal kilns were superior to both metal kilns and nonpermanent mound types in charcoal yield, quantity, and conversion efficiency. Improvements on firing techniques and methods of kiln construction (for local mud and brick beehive kilns) resulted in shorter firing time and charcoal quality consistency. The two to eight cubic meter capacities of both types of beehive kilns are more suitable for rural families and/or communal village practices when such factors as charcoal quality and quantity, ease of operation, firing duration, and capital investment are considered.

Accomplishments

- 18 kilns of various sizes and 12 models (both local and exotic) were built and tested;
- Improved kiln design of mud and brick beehives increased charcoal production to 35-40%;

- The overall energy conversion efficiency was as high as 55-60% for improved mud and brick beehive kilns.

- Improved production methods for earth mound, rice husk mound and sawdust mound yielded a 19-30% charcoal production increase.

- 307 government rural development officials and villagers were trained in improved charcoal production technology.

Significance

There will be a significant saving of the national wood resource when improved charcoal production techniques are widely adopted. The improved charcoal techniques can be used to motivate the establishment of more fuel wood plantations for commercial charcoal manufacturing among rural farmers.

The results of training indicate that the chance of acceptance of these improved technologies among rural charcoal makers is high, if wood is available. In addition, the introduction of the improved charcoal cooking stove has greatly helped them focus on production conservation, and use of charcoal.

WATER LIFTING TECHNOLOGY

Findings

This project studied four types of water lifting systems: solar pumping, wind turbine pumping, gasifier pumping and biogas pumping. One 700-watt solar pump was installed to pump water from a ground water well at Ban Tha Yian for domestic consumption. Another 4,300 watt solar pump was installed at Ban Sukorn, Nakorn Ratchsima to pump water from a storage pond for irrigation purposes. Windmills were installed to pump water for irrigation. From this study it can be concluded that the solar and wind turbine pumping systems are not economically feasible at the present time due to their high investment costs. However, results indicated that the project was successful in initiating rural development cooperation between the villagers and the government and in initiating the application of energy technologies in a rural setting.

Accomplishments

- Water pumping renewable technologies have been installed for field application in rural areas.
- Photovoltaic solar cells for water pumping have been installed and supply the water for the village of Ban Thavium, Amphur Muang, Sakovnakorn.
- Three windmills for crop irrigation have been installed at Ban Sa-moh, Tambon Thu-Thong, Amphur Rhamun, Yala.

Significance

This project has demonstrated that the use of renewable energy for pumping water in the rural areas of Thailand is possible. Valuable information was obtained that can assist the government in decision-making regarding renewable water lifting energy technologies in the development of rural areas.

MICRO-HYDRO ENERGY PRODUCTION

Findings

Four micro-hydro power plants were constructed and installed in Chiang Mai Province and currently supply electricity to three villages and one tin mine. This component actually installed, operated and maintained the technology with the cooperation and involvement of local villagers.

Besides the direct benefit from energy production, there exist some indirect benefits as a result of villager participation in construction work. These indirect benefits include:

1. Increasing Villagers' income and upgrading their standard of living,
2. Initiating a rule of cooperatives in rural development,
3. Fostering close cooperation between local people and the government in rural development, and
4. Transferring a renewable energy technology to rural people.

Accomplishments

- Construction of a micro-hydro powerhouse supplying 118 households at Kam Pong;
- Construction of a micro-hydro powerhouse supply 230 households at Mae Ton;
- Construction of a micro-hydro powerhouse supplying 250 households at Huai Pui;
- Construction of a micro-hydro powerhouse supplying electricity to the Bo Kaeo Tin Mine and surrounding villages;
- A favorable evaluation of the economic feasibility of the four micro-hydro projects;
- An increase in the income level and standard of living of the four villages served by the micro-hydro project;
- A program of education and training for the villagers who provided the labor for the construction and operation of three of the four projects.

Significance

In addition to providing electricity to remote rural villages, this project has provided valuable information on the feasibility of using local village resources for the construction and maintenance of micro-hydropower systems.

VILLAGE WOODLOTS

Findings

Because a fuelwood shortage is becoming a serious problem in Thailand, the Woodlot Project was designed to research, develop, and implement village woodlots in the rural areas. The project has five sub-components: silviculture, economics, land use, sociology, and utilization. The sub-components investigated and selected several species of fast-growing trees and agroforestry systems; gathered and analyzed data (including fuelwood and charcoal use by household) in four Northeastern Provinces, investigated the use of public land, school land and temple land; studied the sociological elements of Thai rural society and surveyed villagers, teachers, and monks to determine their feelings about the woodlot idea; and determined other uses for the wood to be produced (besides fuelwood and charcoal).

Eucalyptus camaldulensis was selected for planting and was planted along with rice and other cash crops on public land. The majority of the villagers, teachers and monks had a good attitude or very strongly agreed with the project concept. Provincial Forest Offices administered the project, oversaw the planting activities and distributed the seedlings. It was found that trees growing in an agroforestry system grew faster. However, because it takes five years for these fast-growing trees to reach maturity, they were not harvested since they were only three years old at project completion.

Accomplishments

- Average charcoal consumption and fuelwood consumption data were gathered;
- 6,000 rai of *Eucalyptus Camaldulensis* have been planted in seven provinces;
- One million seedlings were distributed to villagers in eight provinces;
- A field survey of the socio-economic conditions in four Northeastern provinces was conducted;
- Sociological data was collected on villagers' attitudes and motives towards the woodlot concept;
- Suitable areas for village woodlots have been identified;
- An extensive educational and training program was carried out through use of the radio, TV, and printed materials.

Significance

Since the concept of the village woodlot in Thailand is a new one, this study has been the first step in gathering data concerning public acceptance of the idea of the woodlot, selection of trees, planting specifications, harvesting methods, land utilization and social factors. Establshing village woodlots can slow down the rate of deforestation and increase Thailand's supply of fuel wood.

B. OVERALL PROJECT CONCLUSIONS

- On the whole, the Renewable Nonconventional Energy Project has been highly successful, in meeting its original objectives.

- This Project has played a very important role in alerting the National Energy Administration (NEA) and other branches of the Royal Thai Government (RTG) to the importance of and possibilities for utilizing verious renewable, nonconventional energy resources. It has forced individuals within the RTG to understand and recognize these less well known energy resources and the part each can play in helping to solve both present and future energy problems confronting Thailand.

- This Project is unique in its successful attempt to link together the various activities related to supply and demand of energy so as to optimize the use of all energy resources.

- This Project has developed, and proven the viability of several technologies and systems which can make significant reductions in both the import of petroleum and the decimation of the forests in Thailand.

- An important by-product of this Project is the development of indigenous expertise among the component leaders, their associated staff, and their technical assistants which can be expanded and drawn upon in the future for solving energy problems.

- The information generated from this project can serve as a basis and a tool for broader community development programs and projects throughout Thailand.

Chapter 6

RECOMMENDATIONS

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RECOMMENDATIONS

This chapter has been organized to present Project Component recommendations in 3 general categories: These cover:

A. Continued Investigation
Experimental Equipment and Design Modifications

B. Institutional Support, and

C. Dissemination

A. CONTINUED INVESTIGATION

1. The National Energy Administration and other implementing agencies should continue to investigate, develop,test, and improve new and existing renewable energy technologies.

2. Baseline, Transitional and Evaluation Surveys should be conducted on every project so that success or failure of new technologies can be understood and analyzed for future energy policy planning.

3. Additional measurements of solar radiation and wind should be taken to yield more representative data for further research.

4. It is recommended that work continue on building and strengthening the Energy Master Plan Models and submodels and the Rural Energy Models. Work needs to be done in developing more data bases and subsystem master plans and internal links among the models and submodels. Scenario and Policy Analysis should continue. Answers to "what...if" types of questions in model simulation, analysis, and interpretation should be analyzed with scenario assumptions. Further analysis of the two selected communities in this study should be conducted.

5. Since pyrolysis technology can process a wide variety of organic materials, it has an extensive application in other areas of renewable energy sources. Thus further investigation on other applications of pyrolytic products (char, gas and tar oil) is therefore strongly recommended. It is also recommended that biomass gasification technology use rice husk char briquets produced from PT to reduce costs.

6. The pollution of the environment is of major concern to the Government of Thailand, therefore, the research in the treatment and utilization of industrial wastewaters should be continued until solutions to the problems are found.

7. Research and development activities directed toward even better technology for charcoal conversion from wood should be continued--particularly with fast growing species of trees. Further, the recovery of charcoal fines in large-scale commercial Mangrove charcoal production and the improvement of inferior physical properties of light-weight charcoal briquetting techniques should be pursued. Further research and development should be promoted on both various charcoal end-use specification and standards and on charcoal derived end-products development.

8. Long term outdoor tests should be conducted on the solar stills investigated in this project and an economic and social assessment of the stills should be carried out before they are promoted for field applications.

9. Further experiments should be conducted using solar heaters for tobacco curing, preferably with two identical barns. Also, attempts should be made to test-run the tobacco curing barn as a multiple-crop dryer during the tobacco off-season.

10. The village woodlot project should continue so that the trees can be harvested and the final analyses made.

Experimental and Equipment Design Modifications

1. The datalogger used in automatic data recording for solar/wind energy assessment should be modified for more durability. Spare parts should be sufficiently supplied to ensure continuity of recorded data.

2. The development of the technology for the gasification of biomass should be expanded into the use of all agricultural wastes.

3. Based on the results of the Biomass Gasification Project, it is recommended that the wood gasifiers, fixed-bed crop residue gasifiers, fixed-bed direct fire gasifier systems and crop residues fluidized-bed gasifiers be developed.

4. Because stove development and promotion involve the social customs and habits of millions of people in Thailand and around the world, it is highly recommended that stove research and development be carried on to further improve present designs and find more alternatives for users. The one-hole chimneyed wood stove has attained an efficiency up to only 18-19% but there are problems fitting pots and pans to the stove. Also, the chimneyed rice husk stove is still not popularly used in Thailand. The potential for this stove to become popular is high.

5. Future projects for implementation of water lifting technologies should plan for longer implementation times. Procurement of equipment land ownership problems, land configuration and village leadership are aspects of the project that can effect and lengthen implementation.

6. Careful study should be given to simpler and less expensive designs of all the components for micro-hydro projects in the future--in order to reduce still further the overall cost of each project. Further, all the data necessary for the project design and planning should be carefully collected and recorded prior to implementation (topographic map, detailed profile, geologic structures at the weir site, socio-economic structure of the nearby village, hydrological data of the stream). Since most of the potential sites for micro-hydropower development are in remote areas where the accessibility is rather poor, operation and maintenance problems should be carefully considered in the design stage.

7. Design modifications should be made in the natural convection solar dryer. Trays made from bamboo and nylon net (which are inexpensive) should replace wire-mesh trays. A larger outlet port for ventilation is suggested as demonstrated by the work in progress at King Mongkut's Institute of Technology, Thonburi.

8. It is recommended that the work on forced convection solar hut dryers be continued by investigating high efficiency solar air heaters in relation to small-scale rural industries, drying paddy in the wet season and mathematical simulation. Additional testing is needed on drying of second-crop paddy. Thus, the development of a quality solar collector and low-cost grain dryer is most critical.

9. Within a few years, the research team should be able to further develop the technological process of ice making by solar energy in rural areas. Technically, ice has been made; however, the economic and social aspects will have to be evaluated after further technological improvements.

B. INSTITUTIONAL SUPPORT

1. The NEA should continue to involve its own personnel and personnel from other RTG agencies in programs which alert them and keep them informed regarding the energy problems of Thailand and the potential for solving them with renewable energy resources.

2. That a broad and extensive training program be initiated to develop in-depth manpower capabilities throughout the field of renewable energy--including the technology, the planning and management of the energy systems, and the socio-cultural aspects.

3. The National Energy Information Center (NEIC) should continue to collect and disseminate energy information, particularly in renewable and nonconventional sources in support of integreted national energy planning. It may be necessary to expand and combine existing library and computer facilities to accommodate growth.

4. Two more Regional Energy Centers should be established and existing centers should be maintained.

5. Based on contacts with biomass gasification development teams in Thailand and on perceived future prospects of biomass gasification in Thailand, it is recommended that a Gasification Technology Development Center be created. This Center would coordinate research and development work and be solely responsible for overseeing planning and implementation programs.

6. In Thailand there are quite a few researchers and interest groups working on stove development and promotion. For national stove programs to be directed toward this common goal, leading government agencies need to provide close coordination. It is further recommended that the Government support a nationwide efficient-stove promotional campaign for users and manufacturers.

7. In order to accelerate the process of replacing wood by other fuels, government efforts should concentrate on a strategy to implement an integrated program on fuel wood production and improved charcoal production in rural areas. Further, the government should carry out trials in establishing small tree farms to make charcoal for sale.

8. A permanent unit in the NEA should be established for rapid and systematic expansion of the micro-hydro program in the remote areas of Thailand which are sufficiently far removed from the national electric grid that it will be serveral years, at the earliest, before the grid reaches them. Further, the staff and program for the development of micro-hydro projects should be a part of and very closely tied to each of the nearby Regional Energy Centers.

9. It is highly recommended that forestry officials at the provincial and district levels work in cooperation with agricultural extension workers, community development workers, and rural people, to integrate the Village Woodlot into every element of the social structure.

C. DISSEMINATION

1. The NEA and other branches of the RTG should put special emphasis and effort into dissemination and adoption of the technologies coming out of this project.

2. Special efforts should be made to equip the personnel (especially the technicians) involved in the projects with a good understanding of village life, concentrating on the community's ways of thinking, its behavior and, if possible, important village relationships. Further, training on participatory implementation techniques should be offered and required for technicians working on rural energy development.

3. Small-scale charcoal gasifiers have proven to be very convenient for rural use and should be disseminated. A low-cost dissemination strategy would be the training of villagers in the construction of charcoal gasifiers either in Bangkok or at the Regional Energy Centers.

4. Since, at present, there are more than 40,000 rice mills operating throughout the country, and only two demonstration sites of rice husk pyrolysis, the current situation is inadequate to promote the technology. At least 3 demonstration units should be installed in the Northeastern and Southern regions of the country.

5. Concerning the improved biomass cooking stove, more time and more education are needed for manufacturers to change their attitude and their production techniques. Further, the lack of understanding among users on the criteria for selection and use of efficient cooking stoves was also evident. The government agency concerned should establish a long-range, adequately funded educational campaign program for efficient stoves--particularly through primary and secondary school systems.

6. The diffusion of improved charcoal technology can be spread through the country by training of selected village leaders and charcoal makers. Charcoal Research Center initiated training of officials responsible for rural development and private interest groups, exhibition and demonstration of efficient charcoal kilns as a follow-up program in selected villages and at the RECs, public campaigns for improved charcoal production methods, and creation of public awareness on the criteria for the selection of good quality charcoal and its more efficient use with improved stoves.

7. Public relations dissemination of information on Village Woodlot projects should continue over radio and TV at least once or twice a month. Simple reading materials should be printed and distributed. In addition, an adult education program should be promoted by the Ministry of Education in cooperation with the Royal Forest Department in the village woodlot project areas. Fundamental knowledge of village woodlots, agroforestry, rural environment should be addressed.

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Annex

Thailand Energy Situation 1982

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BALANCE SHEET OF ENERGY CONSUMPTION IN THAILAND YEAR 1982

UNIT : 10^6 LITRES OF CRUDE OIL EQUIVALENT

Types of Energy	Supply					Exports & Re-Exports	Total Consumption	Statistical Difference
	Inland Production Sources		Sub Total	Imports	Total Supply			
	Indigenous	Foreign						
1. Hydroelectric	1,087.140	–	1,087.140	213.178	1,300.318	–	1,300.318	–
2. Coal & Lignite	671.399	–	671.399	113.848	785.247	0.813	766.277	18.157
3. Fuel Wood	646.325	–	646.325	.017	646.342	0.005	646.337	–
4. Charcoal	1,960.294	–	1,960.294	–	1,960.294	26.627	1,933.667	–
5. Paddy husk	623.073	–	623.073	–	623.073	–	142.497	480.576
6. Bagasse	1,241.522	–	1,241.522	–	1,241.522	–	1,158.754	82.768
7. Petroleum Products	221.170	8,408.679	8,629.849	2,341.841	10,971.690	–	10,872.072	99.618
- Premium Gasoline	75.104	626.381	701.485	14.579	716.064	–	632.433	83.631
- Regular Gasoline	54.861	1,054.294	1,109.155	3.534	1,112.689	–	1,208.431	(95.742)
- Kerosene	–	363.926	363.926	68.050	431.976	–	391.358	40.618
- High Speed Diesel	36.559	2,788.515	2,825.074	1,187.530	4,012.604	–	3,954.915	57.689
- Low Speed Diesel	–	74.949	74.949	–	74.949	–	52.164	22.785
- Fuel Oil	19.357	2,512.440	2,531.797	675.422	3,207.219	–	3,203.116	4.103
- Jet Fuel	27.251	862.359	889.610	98.430	988.040	–	1,014.134	(26.094)
- L.P.G.	8.038	125.815	133.853	294.296	428.149	–	415.521	12.628
8. Natural Gas	1,300.620	–	1,300.620	–	1,300.620	–	1,300.620	..
Total	7,751.543	8,408.679	16,160.222	2,668.884	18,829.106	27.445	18,120.542	681.119

GROSS ENERGY BALANCE SHEET

UNIT : 10^6 LITRES OF CRUDE OIL EQUIVALENT

Year	Supply					Exports & Re-exports	Net Imports	Total Consumption	Statistical Difference	Percent Share of Net Imports in Total Consumption
	Inland Production Sources		Sub Total	Imports	Total Supply					
	Indigenous	Foreign								
1973	1,354.161	7,933.841	9,288.002	1,174.350	10,462.352	644.186	8,464.005	9,818.166	–	86.21
1974	1,742.598	7,304.471	9,047.069	1,133.112	10,180.181	180.627	8,256.956	9,999.554	–	82.57
1975	2,089.971	7,738.236	9,828.207	893.898	10,722.105	108.561	8,523.573	10,613.543	–	80.31
1976	2,487.371	8,321.266	10,808.637	1,324.573	12,133.210	28.032	9,617.807	12,105.178	–	79.45
1977	2,333.406	8,960.024	11,293.430	1,824.421	13,117.851	23.746	10,760.699	13,094.104	–	82.18
1978	2,176.395	8,932.155	11,108.550	2,691.624	13,800.174	23.822	11,599.957	13,776.352	–	84.20
1979	4,227.880	9,681.986	13,909.5[illegible]	2,815.088	16,724.954	20.407	12,476.667	16,671.979	52.975	74.84
1980	3,770.815	8,510.747	12,281.562	4,374.840	16,656.402	12.531	12,873.056	16,747.068	(90.667)	76.87
1981	5,320.363	8,633.145	13,953.508	3,569.988	17,523.496	34.689	12,168.444	17,550.832	26.248	69.33
1982	7751.543	8,408.679	16,160.222	2,668.884	18,829.106	27.445	11,050.318	18,120.542	681.119	61.13

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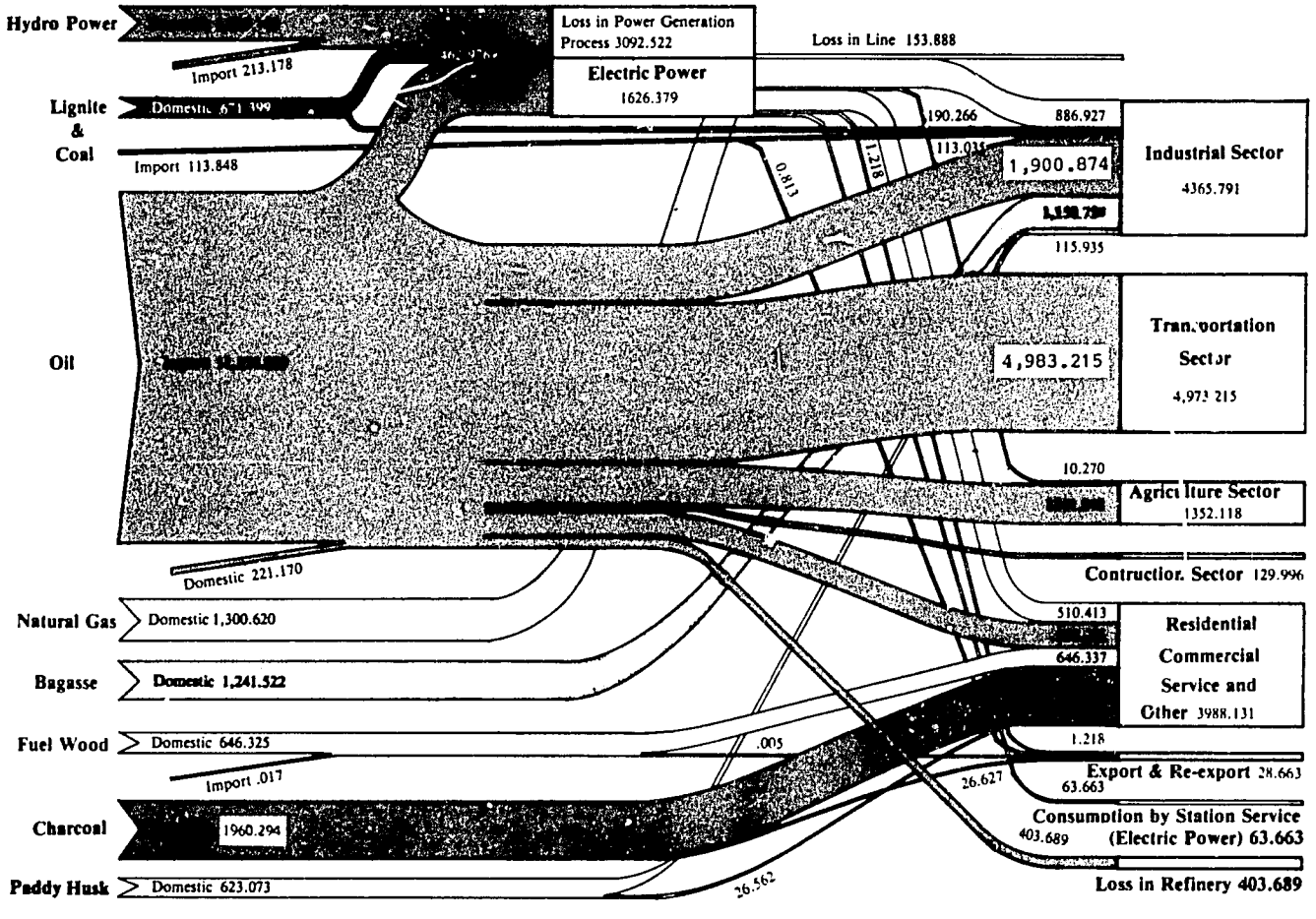
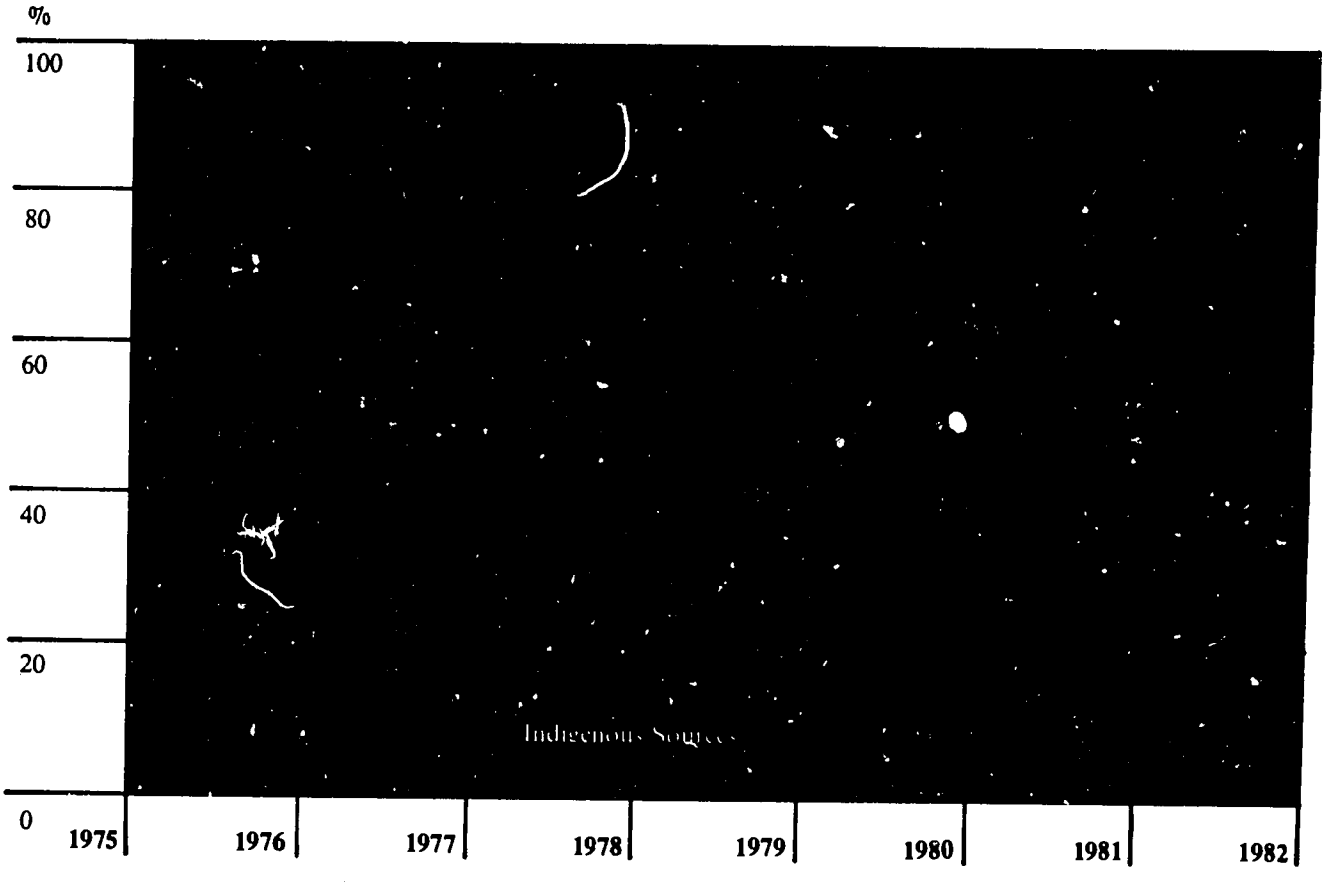
ENERGY FLOW CHART (ACTUAL PERFORMANCE IN 1982)

Unit : 10^6 Litres of Crude Oil Equivalent



SHARE OF ENERGY FROM INDIGENOUS AND FOREIGN SOURCES IN TOTAL CONSUMPTION

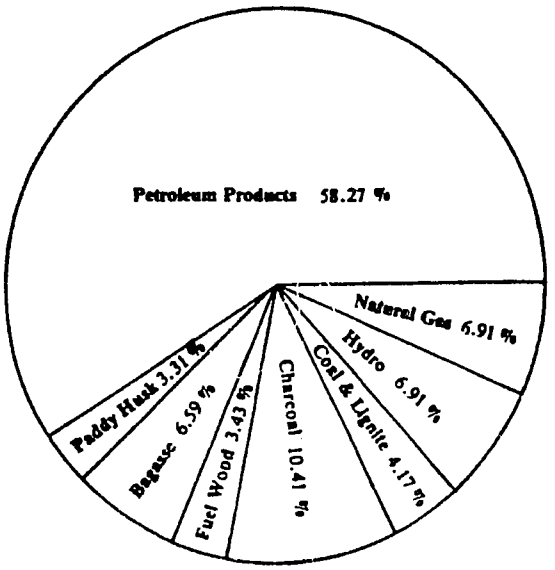


GROSS ENERGY CONSUMPTION

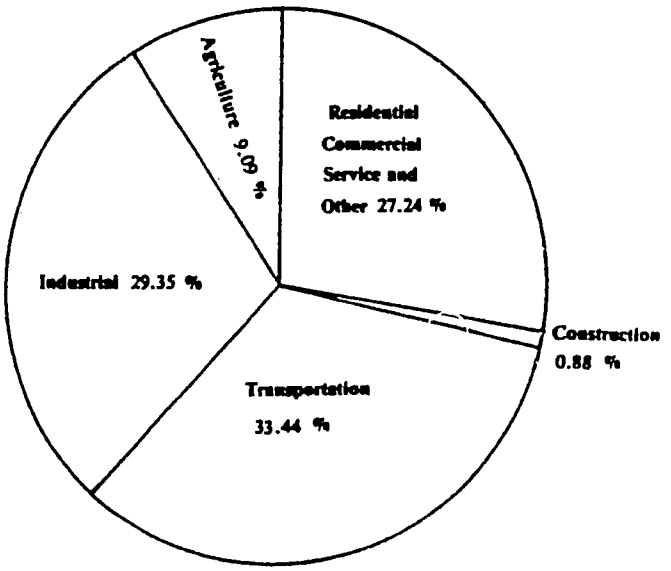
UNIT : 10^6 LITRES OF CRUDE OIL EQUIVALENT

Year	Total	Petroleum Products	Hydroelectric	Coal & Lignite	Fuel Wood	Charcoal	Paddy husk	Bagasse	Natrual Gas
1973	9,818.19	8,422.39	659.94	149.27	51.41	39.25	42.32	453.61	–
1974	9,999.55	8,208.40	843.52	237.90	44.88	23.34	39.16	605.35	–
1975	10,613.54	8,484.15	1,149.96	235.90	42.25	14.15	47.55	639.58	–
1976	12,105.18	9,580.42	1,227.18	276.53	42.38	26.72	41.26	910.69	–
1977	13,094.42	10,720.74	1,113.67	247.41	46.67	20.77	41.99	903.17	–
1978	13,776.35	11,537.77	753.33	320.51	36.72	19.62	45.85	1,062.55	–
1979	16,672.00	12,193.03	1,148.02	440.35	439.22	1,264.70	51.03	1,135.65	–
1980	16,747.05	12,713.55	577.91	468.91	611.79	1,617.57	49.80	707.52	–
1981	17,550.84	12,018.26	1,052.50	503.61	664.58	1,904.80	106.79	1,046.30	254.00
1982	18,120.542	10,872.07	1,300.32	766.277	646.33	1,933.67	142.50	1,158.75	1,300.62

THAILAND ENERGY SUPPLY AND DEMAND 1982



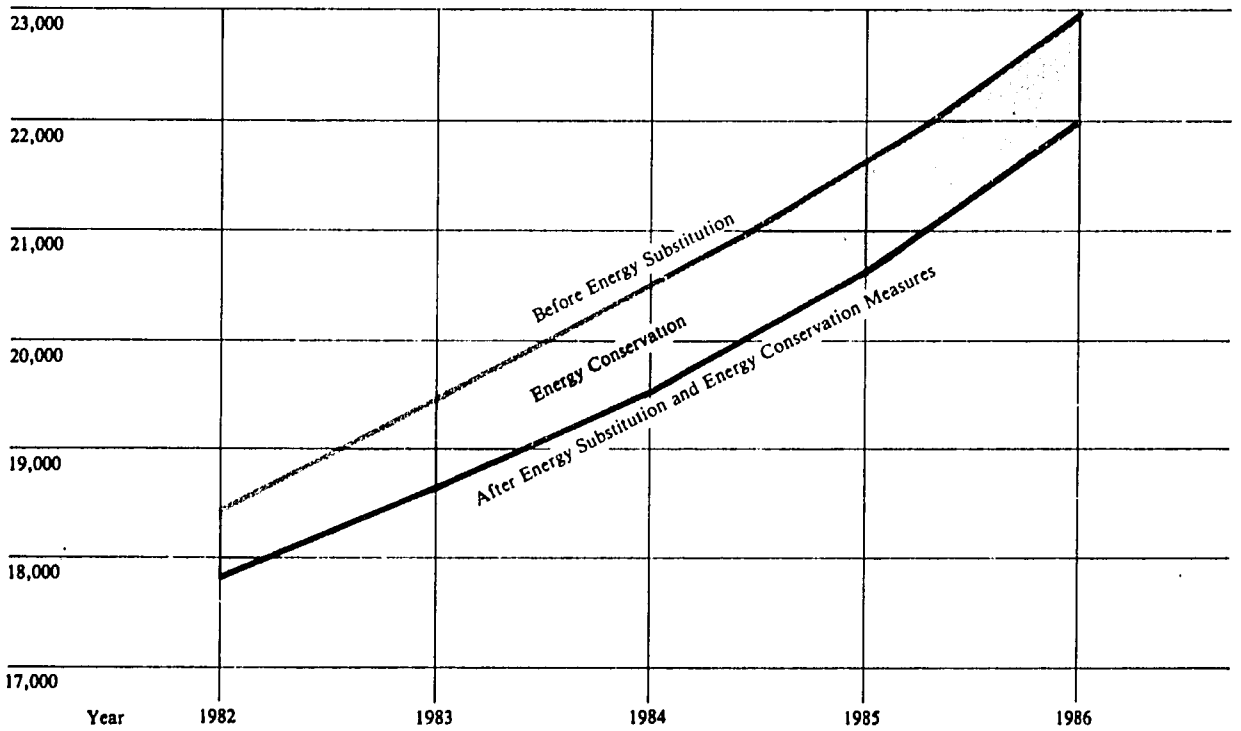
SUPPLY



DEMAND

RESULT OF THAI ENERGY DEMAND FORECAST 1982-1986

Unit : 10^6 Litres of Crude Oil Equivalent



FORECAST OF ENERGY DEMAND

UNIT : 10^6 LITRES OF CRUDE OIL EQ

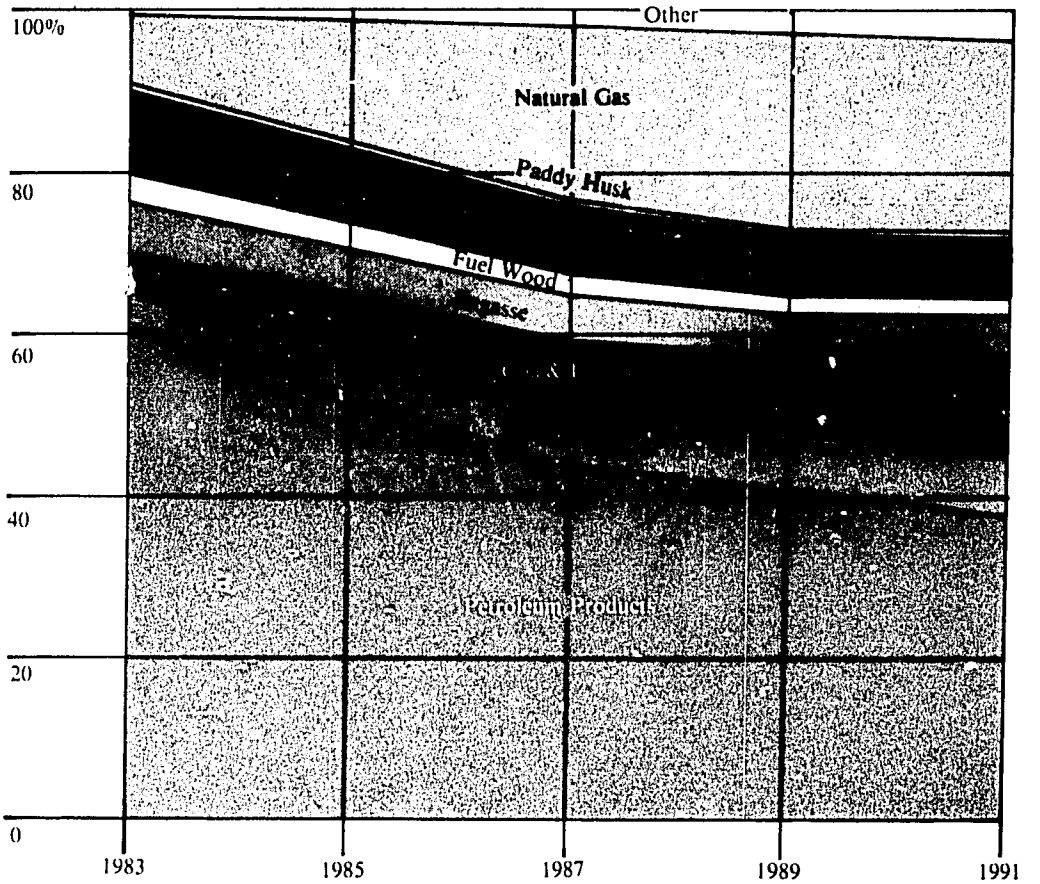
Year	Petroleum Products	Hydro Electric	Coal & Lignite	Bagasse	Fuel Wood	Charcoal	Paddy husk	Natural Gas	Nuclear	Garbage	Mini & Micro Hydro	Biogas	Oil Shale	Alcohol	Fast Growth Plan-tation	Solar Energy	Wind Energy	Geo-thermal
1983	11,360.9	890.6	798.5	1,186.6	653.7	1,966.0	142.8	1,600.9	–	–	6.9	2.2	–	–	–	2.4	0.1	–
1984	11,805.1	964.0	914.6	1,222.7	662.4	1,997.4	143.3	1,748.3	–	–	17.2	3.7	–	35.2	–	3.9	0.3	–
1985	10,840.6	1,223.3	1,334.3	1,246.4	669.8	1,961.3	143.6	2,979.9	–	–	39.5	5.5	11.5	70.4	66.2	6.3	0.5	3.0
1986	10,698.8	1,433.6	1,742.0	1,274.7	676.1	1,987.4	144.1	3,668.6	–	70.8	72.5	7.8	11.5	105.6	66.2	9.8	1.0	5.0
1987	10,202.6	1,469.0	2,175.0	1,305.9	683.9	1,969.5	144.5	4,951.5	–	70.8	86.1	8.1	11.5	105.6	110.4	14.2	1.2	10.0
1988	10,895.6	1,451.1	2,361.7	1,337.6	692.9	1996.0	145.1	5,694.9	–	70.8	99.7	8.5	11.5	105.6	110.4	19.7	1.5	10.0
1989	10,812.7	1,730.0	2,657.1	1,370.3	700.5	2,022.7	145.5	6,098.1	–	70.8	113.3	8.8	19.7	140.8	110.4	26.6	1.8	10.0
1990	10,660.7	1,923.2	2,963.0	1,403.9	709.3	2,051.2	146.2	7,179.1	–	70.8	126.9	9.1	19.7	140.8	110.4	35.3	2.1	10.0
1991	10,703.2	2,116.8	3,412.5	1,494.9	718.8	2,084.6	146.5	6,857.5	–	142.0	141.0	9.0	40.0	140.8	110.0	46.0	2.0	10.0

FORECAST OF ENERGY DEMAND (IN PERCENT SHARE OF TOTAL)

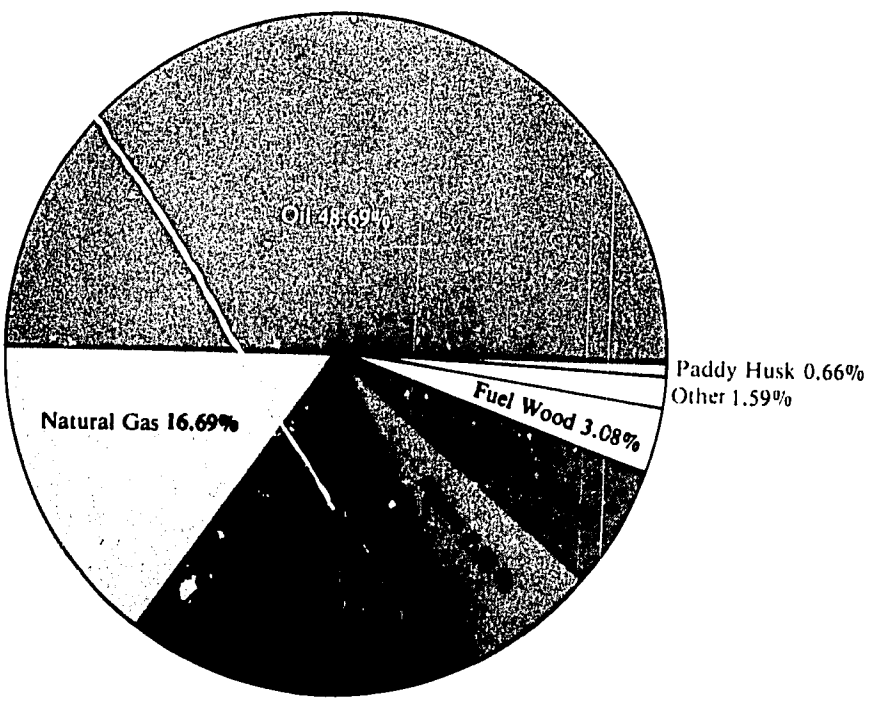
Year	Petro-leum Products	Hydro-electric	Coal & Lignite	Bagasse	Fuel Wood	Char-coal	Paddy husk	Natural Gas	Nuclear	Garbage	Mini & Micro Hydro	Biogas	Oil Shale	Alcohol	Fast Growth Plan-tation	Solar Energy	Wind Energy	Gas Therm
1983	61.04	4.79	4.29	6.38	3.50	10.56	0.78	8.60	–	–	0.04	0.01	–	–	–	0.01	0.0005	–
1984	60.48	4.94	4.69	6.26	3.39	10.23	0.73	8.96	–	–	0.09	0.02	–	0.18	–	0.02	0.0015	–
1985	52.61	5.94	6.48	6.05	3.25	9.52	0.70	14.46	–	–	0.19	0.03	0.06	0.34	0.32	0.03	0.003	0.02
1986	48.69	6.52	7.93	5.80	3.08	9.04	0.66	16.69	–	0.32	0.33	0.04	0.05	0.48	0.30	0.04	0.005	0.02
1987	43.75	6.30	9.33	5.60	2.93	8.45	0.62	21.23	–	0.30	0.37	0.03	0.05	0.45	0.47	0.06	0.01	0.04
1988	43.92	5.85	9.52	5.39	2.79	8.04	0.58	22.15	–	0.29	0.40	0.03	0.05	0.42	0.44	0.08	0.006	0.04
1989	41.49	6.64	10.20	5.26	2.69	7.76	0.56	23.40	–	0.27	0.43	0.03	0.15	0.54	0.42	0.10	0.007	0.04
1990	38.21	7.02	10.82	5.13	2.59	7.49	0.53	26.22	–	0.26	0.46	0.03	0.15	0.51	0.40	0.13	0.008	0.04
1991	37.99	7.51	12.11	5.31	2.55	7.40	0.52	24.34	–	0.50	0.50	0.03	0.14	0.50	0.39	0.17	0.007	0.04

FORECAST GROSS ENERGY CONSUMPTION IN THAILAND

(UNIT: 10^6 Litres of Crude Oil Equivalent)



FORECAST OF THAILAND ENERGY CONSUMPTION



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