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EVALUATION OF RENEWABLE NONCONVENTIONAL ENERGY PROJECT, THAILAND (493-0304)

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ABBREVIATION AND ACRONYMS USED IN THIS REPORT

CMU	Chiang Mai University
CUSRI	Chulalongkorn University Social Research Institute
EGAT	Electricity Generating Authority of Thailand
FAO	Food and Agriculture Organization
ISTPRA	Institute of Science and Technology for Promotion of Rural Areas, Srinakharinwirot University
KMITT	King Mongkut's Institute of Technology Thonburi
KU	Kasetsart University
MET	Meteorological Department
NEA	National Energy Administration
NEIC	National Energy Information Center
PACD	Project Assistance Completion Date
PEA	Provincial Electric Authority
PID	Project Identification Document
PP	Project Paper
PTC	Phanomprai Trading Corporation
REC	Regional Energy Center
RFD	Royal Forest Department
RTG	Royal Thai Government
SNU	Srinakharinwirot University
TISTR	Thailand Institute of Scientific and Technological Research

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I. Executive Summary

A. Conclusions

The Impact Evaluation team considered each of the component parts of the Renewable Nonconventional Energy Project. The majority of the components achieved what they had set out to achieve, with some having current and/or potential benefits that seem well worth the financial investment in this project. Those few components that resulted in decisions to scale down goals or not to proceed, or failed to meet intitial goals, were valuable in the lessons they provided for future activities.

1. The **National Energy Information Center** has been organized and equipped, and is functioning. Its staff has been increased, its data base enlarged, and it is to become a part of the Energy Policy and Planning Division of the National Energy Administration.

2. Four **Regional Energy Centers** have been created, staffed, and equipped, and have been doing excellent work disseminating information developed during the project and since. Workshops and training sessions have been held on fabrication and use of improved cooking stoves and improved charcoal kilns, and on planting and caring for seedlings in village and private woodlots.

3. Support for the **Energy Master Plan** has helped to develop economic models that have already been found useful in national planning.

4. Under the **Village Survey** component, valuable data have been collected that will continue to be useful for future studies. The collection includes valuable information on household fuels, industrial fuel use, agricultural practices, water supply, specific fuel characteristics, and market data.

5. Four **Microhydroelectricity** installations were completed in isolated areas. Hydroelectricity is not only economically more practical than diesel-generated electricity in these situations, it is also financially more attractive to the poorer residents of the villages served than grid power, in those cases where the Provincial Electrical Authority line has reached some of those same villages. While the electricity supplied by these installations to villages otherwise not likely to be served by the national grid in the foreseeable future may not loom large in the national economy, the benefits far outweigh the electrical energy produced. Besides providing the benefits of electricity to isolated villages, the installations have fostered a cooperative spirit that is having beneficial effects on broader village development problems. By virtue of their participation in construction of the installations, and the cooperatives they have formed to operate, maintain, and repair the complete systems, the villagers have acquired skills - organizational, financial, managerial, technical, mechanical - whose value is difficult to overestimate. Furthermore, the results of activity under this component have stimulated greater investment in small hydroelectric installations on the part of the Royal Thai Government, and have helped stimulate a domestic industry in

manufacturing the necessary equipment.

6. **Water-lifting** demonstrations took place, with mixed results that nonetheless contained valuable lessons. While the windmill pumping project failed because of mechanical problems and inadequate involvement of the villagers, a photovoltaic water-pumping installation has demonstrated its technical practicality in relieving villagers of an onerous task.

7. Under the **Biomethanation Systems** component, a study of biogas from industrial wastes was conducted, with the result that several alcohol distilleries are investigating the feasibility of these installations to treat their waste streams. In addition, the National Energy Administration is negotiating with a commercial firm to produce biogas from industrial waste water.

8. The **Solar Thermal Processes** activity resulted in the performance of experiments on solar-drying techniques as planned, with results that provided a better understanding of the economic feasibility and the marketing problems involved. In view of current costs, solar crop drying has not had significant impact in Thailand, and does not seem likely to have in the future,

9. **Biomass Gasification** is an existing commercial operation in Thailand that could probably benefit from some continued research. Under this component, research and development were conducted at three universities, comparing the economic feasibility and assessing the status of various techniques. Twelve units of various sizes were built and operated and the information gathered has improved the knowledge base for expanded industrial use of this technology in Thailand and elsewhere.

10. Work under the **Village Woodlot** component was carried out by the Royal Forest Department, with over one million trees planted in seven Provinces. Many private plantations have sprung up, stimulated by the project, and trees have been planted in home gardens, along fence rows, and between paddy fields. Forests are growing where none grew before, and there is a new appreciation of the environmental value of these trees among many rural residents. The number of trees being planted is still rising, and the only problems seem to be the uncertainty of ownership rights and the eventual use of the trees.

11. **Charcoal production** techniques have been investigated and improvements instituted to increase the efficiency of production. As a result of promotion and training begun under the project and still continuing, private producers are starting to construct the improved kilns.

12. In cooperation with the National Energy Administration, the Royal Forest Department succeeded in developing an **improved cooking stove** that uses more than twenty-five per cent less charcoal - fifty per cent less according to the many users interviewed - than the traditional model in use in Thailand. The wood-fueled stove developed under this project has an even greater efficiency

improvement over its traditional counterpart. This development has sparked the creation of village groups - most of which are owned and operated by women - that are manufacturing and selling the new stoves, the adoption of the new design by manufacturers of traditional stoves, and the organization of a new company devoted to manufacturing, and improving the design of, the new stove. Several thousand of the new stoves have already been sold, and the prognosis for accelerated sale is promising. Public interest in the new stoves seems to be growing, and the World Bank is preparing a major effort to accelerate and expand dissemination of the new model.

13. An assessment of solar and wind resources has been performed and the data collected will be useful for some time.

14. Experiments were performed on pyrolysis of rice husks that provided useful information by use of which the process can be evaluated. Pyrolysis of rice husks is not seen as a useful technology, particularly in view of the more practical gasification processes that exist, and the successful briquetting of the husks that has been developed.

To summarize:

Of the fourteen components that comprised the project as implemented, four were found already to have had significant beneficial impacts - and continuing impact - on the welfare and economy of rural Thailand. These were:

- Regional Energy Centers
- Microhydropower
- Improved Cooking Stoves
- Village Woodlots

Work on five others was found to have significant potential impact on both the rural and national economies:

- National Energy Information Center
- Energy Master Plan Support
- Village Surveys
- Improved Charcoal Production
- Solar/Wind Resource Assessment.

By far the most impressive consequences of the Renewable Nonconventional Energy Project are the results of the efforts in microhydroelectricity, improved cooking stoves, and village woodlots.

B. Recommendations

The impact evaluation resulted in a series of recommendations to the Government that can be summarized as follows:

- **National Energy Information Center** -- The NEIC should take steps to respond more rapidly to search queries, establish links to other energy-related data bases in Thailand, and institute procedures to encourage a regular flow of information to the Regional Energy Centers.

- **Regional Energy Centers** -- The staff of the RECs should be increased to permit greater promotion not only of developments in cooking stoves and tree planting, but of public awareness of the interdependence among cooking, charcoal production, and deforestation.

- **Energy Master Plan** -- The National Energy Administration (NEA) should continue to use the models developed under the project, expanding on the household- and rural-energy activities in each model. Improved data collection, through the NEIC, should be undertaken.

- **Village Survey** -- Data collected during the project should be made more available, and useful, by reorganization and publication by the NEA. Additionally, NEA should conduct a survey within the next three years to assess impacts that may become more apparent by then.

- **Microhydroelectricity** -- The Provincial Electricity Authority (PEA) and the NEA should accelerate the pace of their policy discussions to permit sell-back arrangements for electricity produced by the private sector, including some the the cooperatively run microhydroelectric installations. The NEA should assist the cooperatives in devising a more appropriate form of financial accounting.

- **Water-Lifting Technology** -- Further photovoltaic or windmill water-pumping schemes should be pursued by the Government only after careful economic and technical comparisons among all systems available. The World Bank/UNDP Solar Pumping Field Manual is a useful tool for such comparisons.

- **Biomethanation Systems** -- Review of the commercial proposal for treatment of industrial wastes, with biogas as a useful by-product, by a disinterested outside expert should be seriously considered by NEA. Future community biomethanation systems should be undertaken only with assurance of public understanding and willingness of villagers to participate.

- **Solar Thermal Processes** -- Pending changes in energy-pricing and environmental policies, NEA should encourage the use of solar crop dryers only for industries where they are currently commercially viable. Without stricter, and enforced, government standard on the quality of dried foods, interest in this process and possible export markets are not likely to expand. For tobacco curing, NEA could assist by encouraging research on reducing the cost of systems that

displace fuel wood or lignite.

- **Biomass Gasification** -- NEA should consider continuing support for research on some gasification technologies, and on improving the thermal efficiency of rice-husk gasification. The PEA could help accelerate private initiatives in this field by relaxing its rules against purchasing electricity generated by the private sector.

- **Village Woodlots** -- The Royal Forest Department (RFD) should take the initiative in exploring markets for trees being grown on woodlots, clarifying land-tenure and tree-ownership rights, investigating the use of other species to create biological diversity, and improving extension services to the villages and private tree growers.

- **Improved Charcoal Production** -- NEA and RFD should accelerate discussions already under way regarding definition of legal charcoal production and sale, giving particular attention to linking production with fuel-wood plantations. Improved coordination, by the two agencies, of promotion efforts under this activity and the cooking-stove and woodlot activities is the best way of multiplying benefits under each of these programs and decreasing deforestation pressures from fuel-wood use.

- **Improved Cooking Stoves** -- In view of the important commercialization achievements of the stove development under this project, the Government should continue supporting this program by soliciting outside support, if necessary, identifying additional marketing arrangements, and encouraging village manufacturing groups by providing managerial and organizational assistance.

- **Solar/Wind Resource Assessment** -- NEA should continue to review budget requests of the Meteorological Department of Thailand to insure that its Center for Solar and Wind Calibration has adequate staff and data-collection and -analysis capabilities to meet national needs.

- **Pyrolysis of Rice Husks** -- Continued support of pyrolysis projects aimed at commercialization is not recommended.

II. Introduction

The Renewable Nonconventional Energy Project (493-0304), a joint effort of the U.S. Agency for International Development (USAID) and the Royal Thai Government (RTG), was designed to reduce Thailand's dependence on imported (fossil-fuel) energy through the development and application of Thailand's renewable-energy resources, arrest environmental degradation caused by deforestation, and create opportunities for increasing income in rural areas. Project activities began in 1981 and ceased in 1984 at the scheduled (extended) Project Assistance Completion Date (PACD). Although an interim evaluation of the project was performed in September, 1982, the final evaluation of the impact of the project was delayed until 1986, to allow time for the effects of the project components to become clear, primarily because the development and/or application of many of these components was not achieved until 1984. This report presents the result of that final impact evaluation.

A. Purpose of the Evaluation

The purpose of this evaluation, as detailed in the Scope of Work (Annex 1) is to assist both USAID and the RTG in six major ways:

1. Assess the achievements of project outputs and measure the degree to which the project purpose and end-of-project-status have been realised.

2. Examine the degree to which the technologies and information generated by the project are influencing energy-consumption patterns of the people involved, especially the social impact on rural villagers.

3. Address what technologies developed under the project have proved to have high potential for commericalizaton and dissemination and future active roles of already established institutions.

4. Assess any environmental and ecological impacts from the adopted project activities.

5. Explore both private- and public-sector activities to determine if development activities are being undertaken and, where undertaken, evaluate the magnitude and quality of the implementing agency's activities. A similar search will be made of private industry and private individuals, to the extent they can be identified, in order to determine how private-sector investments are now being made for developing energy applications.

6. Make recommendations concerning additional or alternative uses of the information and/or the generation of additional informaton or activities for possible future applications.

B. Methodology

The evaluation team, ably assisted by USAID/Thailand's Office of Engineering and its Program Office, consisted of an energy specialist, an energy economist, a forester and wood-products use specialist, and a social scientist. (See Annex 1.) The team began its work by reviewing the project files, documents, and reports made available by USAID. These were supplemented by other project-related documents obtained from other sources (e.g., RTG, universities, the Food and Agriculture Organization - FAO) during the course of the evaluation.

Interviews were held in Bangkok with National Energy Administration (NEA) officials, project-component team leaders and others who were involved in implementation of project components, and specialists from universities and other organizations whose input was felt to be pertinent.

Field interviews were then held with directors and staff of Regional Energy Centers (RECs) (part of the project's institutional development), private manufacturers of equipment developed under the project, villagers, owners of private woodlots, and university investigators involved in project-component research and development. Site visits were made to a variety of field installations of energy facilities accomplished during the project or as a result of the project activities, and to villages involved in project implementation. Finally, discussions were held with USAID personnel in both Bangkok and Washington.

C. Background

Planning for the Renewable Nonconventional Energy project began in 1978 with approval of the Project Identification Document. Following a detailed project-design phase, final authorization was granted July 31, 1979, and the Grant Agreement between USAID and the RTG was signed August 16, 1979. This provided for $5,000,000 in grant funds from the U.S. Government plus $3,149,900 from the RTG, with an additional $1,010,000 from the United Nations Development Programme (UNDP) and the Asian Development Bank for the development of an Energy Master Plan.

There followed a series of delays that, as the September 1982 Evaluation stated, "were the result of a number of factors, including waiting periods associated with the RTG budget process, and the complex approval processes for component work plans."[1] During this period, AID also selected and negotiated with a consulting firm to provide a variety of coordinating and technical services to the RTG implementing agency (the National Energy Administration - NEA), the Project Coordinator provided by the Contractor set up activity in Thailand, and the RTG set up an administrative system to work with both USAID and the Contractor. Preparation of work plans was begun late in 1980, but actual substantive activity did not begin until the first quarter of 1981, when work on project components began.

The Project Assistance Completion Date (PACD), June 30, 1984, was extended to October 31, 1984 to permit the completion of some of the development begun under the project, and to allow time and funds to complete training, to hold the final workshop, and print the final accomplishment reports.

D. Summary of the Project Paper

The original project design [2],[3] was based on two major activities - institutional development and acceleration of the use of proven cost-effective energy technologies in rural areas. Each of these activities involved several components:

Institutional Development:

- Establishment of a National Energy Information and Documentation Center to be a central source of energy-related information in support of RTG energy policy and planning.

- Establishment of six Regional Energy Centers to provide regional focal points for energy data collection, project implementation, and technology and information dissemination.

- Assessment of renewable and non-renewable (energy) resources, including not only "solar, biomass, and micro-hydro energy," but also lignite, tar sands, and oil-shale reserves and geothermal-energy potential.

- Monitoring of developments in energy technologies, specifically, at the outset,

  + solar-thermal energy conversion
  + biomass-energy conversion
  + oil-shale uses and applications
  + photovoltaics
  + wind-energy conversion

- Support for Thailand's Energy Master Plan, including:

  + pre-feasibility/feasibility studies of micro-scale renewable-energy alternatives
  + survey of rural energy use
  + studies of village resources
  + feasibility studies of village (micro-scale) energy systems
  + staff support
  + training
  + energy conservation

Rural Oriented Technologies

- Biomass conversion

  + improved cooking stoves
  + biomethanation (biogas)
  + improved charcoal production
  + pyrolysis of agricultural residues
  + energy conservation for small industry
  + integration of biomass-conversion systems

- Microhydropower

- Solar drying and distillation

- Water lifting, including:

  + wind
  + biogas
  + photovoltaics

- Village woodlots

All of these activities were to involve comprehensive economic and social analyses, with particular attention to the status of women as affected by project activity.

In the event, however, as the project progressed, some of the components were dropped and others changed. Thus, by the PACD, the components actually involved in implementation were:

A. National Energy Information Center
B. Regional Energy Centers (four - scaled down from six)
C. Energy Master Plan Support
D. Village Survey (dealing only with renewable-energy sources)
E. Micronydroelectric Systems
F. Water-Lifting Technology
G. Biomethanation Systems (Industrial Biogas - dropped after initial study)
H. Solar-Thermal Processes (emphasis on crop drying, with some work on distillation)
I. Biomass Gasification (wood, charcoal, rice husk)
J. Village Woodlots
K. Improved Charcoal Production
L. Improved Cooking Stoves
M. Solar/Wind Resource Assessment
N. Pyrolysis of Rice Husks

REFERENCES

1. Development Sciences Inc., 1982. "Thailand Renewable Nonconventional Energy Project: An Evaluation." September. Report to USAID/Bangkok.

2. USAID/Thailand, 1979. Project Paper: Thailand - Renewable Nonconventional Energy. July.

3. USAID/Thailand, 1979. Annexes to Project Paper for Renewable Nonconventional Energy Project (Project No. 493-0304). July.

III. Findings

A. National Energy Information Center

1. Background

Though technically established before the Grant Agreement for this project was executed, the National Energy Information Center (NEIC) received its largest boost from the Renewable Nonconventional Energy Project. Created November 21, 1978 (subsequent to PID approval) by Cabinet decision, the NEIC was designed to be a central source of information to support energy policy and planning. The NEIC received four-year funding under this project in 1980.

2. Achievements

With this support, and with the technical assistance provided under the project, NEIC established procedures to create and maintain a modern information-handling system. It updated and combined existing collections of the NEA Regulatory Division and the NEA library. It increased its staff from the original three to eighteen, and enlarged its information base by cooperative arrangements with the Asian Institute of Technology (AIT) and the ESCAP Bibliographic Information System (EBIS). In addition, by virtue of the expansion of its activities, the NEIC is to become a part of NEA's Energy Policy and Planning Division under a new reorganization. Finally, supported by USAID funds, NEIC purchased and installed a Hewlett Packard HP 3000/40 minicomputer to handle its expanding information base.

3. Impacts and Benefits

Prior to USAID funding, the NEIC consisted of the Regulatory Divison's collection of electrical safety standards and other data, and the NEA's library of "engineering textbooks, a few serial titles (received and kept for the most part by the Directors of the Divisons), and a considerable number of energy reports" (between 2,000 and 3,000). Limited budgets and staff restricted the information services available. With the advent of USAID funding, "a new dimension was given to the development and growth of the afore-mentioned collections - a slow but definite entrance into the world of specialized information centers."[1]

Perhaps not surprisingly, in view of Thailand's overall energy problems, the NEIC reports that although a substantial portion of the requests for information concern renewable-energy issues, the majority of requests concern petroleum.

4. Factors that helped or hindered

Without a doubt, the USAID funding is responsible for the NEIC's current capabilities. Nonetheless, the NEIC staff feels strongly that the USAID conditions for expenditure of project (grant) funds hindered progress. By requiring "that expenditures of grants should proceed according to the system already in existence within the Thai Government," project personnel had to "acquire approvals through bureaucratic channels which caused considerable delays, particularly in the process of the acquisition of new materials."[2]

In this post-project period, some users feel that the NEIC's services would be more widely used - and useful - if NEIC were to advertise its services, provide computer links, and facilitate information retrieval from its database.

5. Results and Conclusions

There is no doubt that the consolidation of existing information collections and facilities has eliminated unnecessary duplication, and that the expansion of the information base has great potential benefits for users of the NEIC. Nevertheless, the lack of the capacity to link their data base electronically with other data bases in Thailand, such as the Renewable Energy Resource Information Center (RERIC) at AIT AND EBIS, severely limits NEIC's usefulness. (The arrangement with EBIS was a temporary one, allowing only a one-way storage of information from NEIC in EBIS's data bank. It did not give NEIC access to the rest of that data bank.) Users of NEIC's data base, reported to be between sixty and seventy per month, are "internal" (i.e., NEA personnel) or from the universities. It is not clear, however, how many university users there are, or how useful the NEIC has actually been to them. King Mongkhut Institute of Technology, Thonburi (KMITT), for example, has a direct computer link to the AIT data base, while the NEIC is not equipped to handle electronic information exchange. There is evidence also that some university users feel it is easier to contribute information to the NEIC than to obtain it from the system. Certainly, the speed with which the system responds to search queries leaves something to be desired. Finally, a serious gap in the data base is created by lack of data, information, and case histories from the Regional Energy Centers.

What is clear is that organization of the NEIC, the consolidation of collections and facilities, the larger and better trained staff, and the installation of the HP 3000/40 minicomputer have combined to give Thailand an energy information center with enormous potential benefits to Thailand and its ASEAN partners, in facilitating the flow of energy information. It potential contribution is being recognized in an impending reorganization, when it will be made part of the Policy and Planning unit in the Office of the Prime Minister.

6. Recommendations

a. NEIC clearly should update the data-base programming to speed up the system's response to search queries.

b. Electronic information-transfer links - by dedicated line, if necessary - should be established by NEIC with other important, related computerized data banks, such as RERIC at AIT, and EBIS at ESCAP. If NEIC is concerned about sensitive data bearing on national policy or security, that material can be protected from unauthorized access by suitable programming. Other information, however, should be freely and easily available.

c. NEA should establish procedures for a regular flow of information from the RECs to the NEIC. This should include survey data, operating statistics, case histories, and any other pertinent information bearing on woodlots, cookstoves, biomethanation, charcoal, all applications of solar energy, uses of biomass, and microhydroelectricity.

REFERENCES

1. National Energy Administration. 1984. The Establishment of the Thailand Energy Information Center in Thailand. p.32. Bangkok: NEA.

2. Ibid., p.33.

B. Regional Energy Centers

1. Background

The Project Paper called for the establishment of six Regional Energy Centers (RECs). The Work Plan approved on January 11, 1982 provided for only four centers, however, but noted that two more centers were to be established by 1986, two years beyond the PACD.

2. Achievements

The four RECs established under the project, located in Phitsanulok, Maha Sarakham, Nakhon Si Thammarat, and Ratchaburi, were all visited by the evaluation team. They all have developed alternative-energy priorities for their regions. They have collected survey data and have served as training centers and dissemination centers - in a broad sense, providing extension services. Among them, the RECs have held:

- four workshops on improved cookstoves;
- thirteen training sessions for cookstoves;
- eight workshop/training sessions (with the RFD) on planting and caring for seedlings of rapidly growing tree species; and
- seven training sessions on construction and use of improved charcoal kilns

While their activities have focussed on improved cookstoves, improved charcoal production, and village woodlots, they have also demonstrated, adopted, and disseminated information on windmill water-pumping, solar-thermal technologies (crop drying, water heating, and distillation), the use of photovoltaics (for lighting, domestic water supply, battery charging, and vaccine refrigeration), and biomethanation.

3. Impact and Benefits

Detailed discussion of the economic, social, and environmental benefits of each of these achievements will be found in the sections on those specific project components. They are noted here, however, because the RECs have played a major role in achieving these benefits. The frequent presence of the REC staff in the villages during periodic visits for promotion, training, or in response to requests for assistance, and their work on village projects have been the principal aspects of that role.

The RECs have been responsible for the establishment of commercial manufacture of improved charcoal cookstoves - by village groups, individual village entrepreneurs, established manufacturers of traditional stoves, and at least one large manufacturer established specifically to fabricate and market these stoves. They have accomplished this by virtue of demonstrations, training, providing consultant services to manufactures, and by providing initial markets for the new products. Their promotion of this technology has resulted in the sale (and use) of several thousand of these

stoves. Production rates are rising and at least one manufacturer has produced a modified version with the same efficiency and (presumably) life, but with a lower manufacturing cost.

The Eucalyptus woodlots (forests, really), fence rows, windbreaks, and household plantings that can be seen throughout much of Thailand owe their existence to the combined efforts of the RECs and the RFD in promotion, training, and distribution of seedlings. While the use of improved charcoal kilns has been slower to catch on than the cookstoves or the tree plantings, several commercial charcoal manufacturers have adopted the new designs.

4. Factors that helped or hindered

The accomplishments of this project component have been impeded by the implementation delays experienced under the project. The earliest REC to be completed, at Mana Sarakharm, was actually started (FY 81) before USAID funding was available through NEA. Nevertheless, this center was not completed until FY 83 with a starting staff of two. The last to be completed, at Nakhon Si Thammarat was finished in 1985, long after the PACD, and although construction of the REC at Ratchaburi was completed in April, 1984, its equipment did not arrive until the following November. Thus, construction, staffing, and equipping of the Regional Energy Centers have been completed for only between one and two years.

5. Results and Conclusions

The decision to confine the project activity to four RECs was wise in view of the delays that plagued project implementation; the fourth center was completed only shortly before the (extended) PACD. Delays continued to hamper full operation of two of the four RECs even after the PACD, in terms of unavailability of sufficient staff to meet their responsibilities and delayed arrival of equipment that had been ordered under the project. (At least one of the RECs resorted to making much of its furniture in its own workshop.)

In spite of the delays that impeded the initial activities of the RECs, their achievements are impressive. It seems clear that even more would have been accomplished by this time if they had been able to get an earlier start.

The establishment of the RECs in each of the regions of Thailand seems to have had a definite beneficial impact on public awareness of energy issues, and is beginning to have an influence on energy-consumption patterns. Its mere presence in the villages during periodic educational or training visits or for maintenance or repair of renewable-energy installations, is important in demonstrating the Government's commitment to long-term rural welfare.

6. Recommendation

Though budgetary problems may make it difficult, the NEA should give serious consideration to increasing the staff of the RECs by at least 25 per cent. This would permit the RECs to expand their activities in promoting the improved charcoal stoves and tree planting, in particular, and in educating rural residents in the intimate links among cooking, deforestation, and charcoal production. The measure of success in carrying out this recommendation will be the increase in number of stoves manufactured and sold (and used), the number of trees planted, and the number of charcoal manufacturers who adopt the improved techniques. The basic overall measure of course, is the extent to which this effort decreases the rate of defores ation.

C. Energy Master Plan: Sectoral Energy Planning Models

1. Background

An important component in Thailand's energy policy analysis is the development of energy planning models. In 1980, development of an Energy Master Plan of Thailand (EMP) was undertaken by NEA under the sponsorship of the Asian Development Bank (ADB) and the United Nations Development Program (UNDP). The major objective of the EMP was to provide NEA with the capacity to conduct "macro-energy planning and prepare a long-range, sector-wide energy plan for Thailand."[1]. Two goals of the EMP were to assist in devising appropriate policies that would both reduce petroleum dependence and improve energy management.

In 1980, USAID assistance from the Renewable Nonconventional Energy Project was used to supplement efforts of the EMP in the rural and renewable-energy areas. The original project paper called for prefeasibility/feasibility studies of renewable-energy alternatives, rural-energy surveys, detailed village-resource studies, and feasibility of village energy systems. However, the work plan wisely narrowed the scope to concentrate on:

- support of further development of the Rural Energy Use submodel and other submodels (transportation, electricity, the textile industry, paper industry, and the Urban Household submodel) for the EMP; and
- development of micro-level energy models for the rural-community and household levels.

2. Achievements

Development of each model required defining and programming the relationships in each sector, and obtaining data to test the models. The models developed under this component include:

- Rural Energy Use Model (Meta Systems, Inc.);
- Improvements on the EMP submodels (transportation, electricity, textile and paper industry - developed by NEA);
- Household Energy Model (Meta Systems, Inc.);
- Rural Community Development Model (NEA).

All models developed under this component were built to be used independently, as well as to be able to be incorporated into the EMP. Each model used optimization techniques, usually linear programming, to maximize income or minimize energy costs.

3. Impacts and Benefits

Development of these models has been important to NEA in terms of increasing their capacity for systematic analysis of energy relationships at the macro and sectoral levels, and providing a basic framework that can be used for focussing on future data needs. The primary contribution from the NEA/USAID component was to provide support for NEA to focus more closely on rural energy sectors, which often receive little attention in national energy modelling and planning. The development of more complete EMP submodels also allowed more in-depth analysis of these sectors and the disaggregation of the EMP. The advantage of having separate submodels is that it saves computer time and allows for greater detail in each subcomponent. The usefulness and meaningfulness of the results, thus, is improved.

Through the development of these models, NEA also had a systematic checklist of data needs. As a result of defining their data needs, NEA has been able to improve, and focus more closely their 1985 rural energy survey.

4. Factors That Helped Or Hindered

Time limitations meant that certain submodels (Urban Household and Tertiary submodels) were never completed by the end of the project. Another major constraint in the testing of each submodel and its ultimate usefulness as a policy-making tool was the lack of adequate data. At the time of the project, most rural energy data could not be readily used because they were either highly aggregated or too site specific. Data from the other components of the project, such as the Rural Energy Surveys, and Baseline Energy Surveys, in combination with other secondary sources, helped overcome this constraint for NEA to some extent. NEA has not realized the potential of the models, however, because of their high data requirements.

5. Conclusions

By the end of the project, the contribution of the NEA/USAID submodels to general energy planning in Thailand was an important first step towards better policy analysis of rural-energy issues and interactions between national- and rural-energy issues. Development of these models produced a systematic outline of rural-energy relationships and pointed to important data requirements. Second, this component gave NEA the opportunity to define and expand its data base better and improve data-collection techniques. Model testing helped point out areas of data strengths and weaknesses. As a consequence of the project, NEA conducted further rural-energy surveys in 1985 to improve their data and provide time-series information.

Specifically, the results from these models provided NEA with insights on relationships between energy demand, income-distribution impacts, energy-supply constraints, and optimal conversion-technology priorities in the rural areas at the household and community levels. The revised Rural

Energy Use model has pointed to the need for greater concern regarding forest depletion and the implementation of fuelwood plantations. The EMP submodels have shown the energy conservation potential in the textile and paper industries. The Household Energy Model can show the scarcity values (implicit costs or shadow values) for resources and technologies related to energy use in the rural areas. These values are extremely important to understanding consumer behaviour and setting pricing priorities. Although the Rural Communtity Development model was only applied to two villages, both cases showed the relationships to income generation and energy-system adoption. As a consequence of this modelling effort and the success of other project components, rural energy planning has received greater attention and emphasis in the Sixth Five-Year Plan.

6. Recommendations

These energy planning models are extremely important to Thailand's energy and resource-use planning. Almost all models will require some improvements to increase their accuracy and potential use. Specifically, NEA should endeavor to improve these models in the following areas:

- the collection of data on household energy demand to obtain energy-price and -income elasticities through other types of econometric models;
- systematic establishment of data banks for all models;
- expansion of household and rural-community activities in each model; and
- greater in-house (NEA) training on modelling.

Data collection by NEA could be improved through use of the Regional Energy Centers (RECs), which have access to village-level energy supply and demand information. Since they have carried out technology-related surveys, some staff at the RECs have the necessary training in survey techniques and the RECs would only require additional staff and support from NEA for development of a questionnaire. Consumer behavior for rural energy resources has been found to be difficult to predict from energy-pricing studies, however, [2] partly because the models used are not responsive to the fact that many rural fuels are free. Therefore, efforts by NEA must focus on those key resources that are critical to rural energy use, such as fuelwood and charcoal, and should try to determine implicit prices as provided by the some of the models.

Finally, the National Energy Information Center should use its computer for systematic compilation and organization of energy data. This would increase use of the center and create a focus for energy information in the country. Financial support for energy modelling, as well as instruction for NEA staff in these techniques, might be provided through regional energy programs, such as those of the Association of Southeast Asian Nations (ASEAN) or the World Bank's Economic Development Institute.

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D. Village Surveys

1. Background

The village survey component was originally designed to comprise three phases: the Baseline Surveys, to describe the conditions in villages prior to the introduction of new energy technologies; Transition Surveys, to collect data on the process of introducing such technologies and testing them on the site; and Evaluation Surveys, to assess the results of the introducton of the new technologies in relation to the general economic and social conditions of the villages.

2. Achievements

The Baseline and Transition Surveys were successfully conducted, although with overlapping of time and agencies responsible for conducting them. The Evaluation Survey, however, was not carried out, except for some informal component-specific evaluations made by each team. (An Interim Evaluation of the overall project, however, was conducted in 1982 by Development Sciences Inc. for USAID/Bangkok and the National Energy Administration.)

a. Baseline Surveys

The main national Baseline Surveys were conducted primarily in 1980-1981 by the Coordinating Contractor with research teams from Chulalongkorn University Social Research Institute (CUSRI), Chiang Mai University, and Khon Kaen University as consultants. They investigated abou 1900 housenolds from fifty villages in ten selected provinces: Petchaburi, Nakhon Ratchasima, Si Sa Ket, Kam Phaeng Phet, Lampang, Songkhla, Chantaburi, Roi Et, Udon Thani, and Chiang Mai. Parts of the Baseline Surveys (for the microhydroelectric installations and windmill and photovoltaic water lifting) and the main Transition Surveys were carried out by NEA in 1983-1984. The purpose of the surveys was to provide general data on village activities involving energy use. The data were intended for use in selecting sites where technologies would be introduced and in comparing with data to be obtained after installation of the systems. Also, it was hoped that each component team would use the data for the design and implementation of the systems under the project.

The Baseline Surveys contained data on the following topics:

- **Cooking** -- fuel selection and consumption, foods consumed, stove design and use (for information on household fuel use);

- **Industry** -- fuel use, level of production, production costs, labor productivity, production technology, marketing of inputs and outputs, financing (for information on industrial fuel efficiency and pricing);

- **Agriculture**-- crops, planting cycle, land tenure, size of holdings, use of agrochemicals and equipment, extent and method of irrigation, yields, residues (for information on potential availability of biomass resources for energy conversion and location of village woodlots);

- **Fuels** -- moisture content and calorific value (from measurements on approximately 1,000 samples at Kasetsart University School of Forestry), prices, yields, locations, uses, preparation, conversion, and distribution;

- **Water supply** -- location of source, allocation, level of consumption, uses; and

- **Markets** -- prices of major fuels, appliances, industrial products and sources of fuels sold.

Since some of the planned systems were installed in villages not included in the main Baseline Survey, it was nescessary to conduct additional Baseline Surveys. These were done in 1983 and 1984 for fifteen villages in four provinces (Yala, Chiang Mai, Sakon Nakhon, and Nakhon Ratchasima) at the same time as the Transition Surveys for these villages were being carried out.

b. Transition Surveys

The Transition Surveys were carried out by NEA and were intended to record data on changes and problems that might occur during the implementation of each technology-related component. This included information on:

- availability of village labor for construction;
- availability of villagers to be trained to operate, use, and maintain the installation; and
- information on establishing a pattern of ownership, administration, and dissemination of the system.

The survey was normally conducted in the period of two to three weeks preceding the implementation, and lasting until two to three weeks after the implementation. A transition survey was done for each of the following components: Village Woodlots, Microhydroelectricity, Water Lifting (windmill and photovoltaic), and two non-USAID-supported community biogas digesters.

3. Impacts and Benefits

The detailed study of secondary data at the preparation stage for the Baseline Surveys contributed significantly to the identification of regions where certain sources of energy were located, generally providing a firm statistical basis for what was otherwise felt to be "common knowledge." It was found that the South had sufficient wind energy for the windmill water lifting; the Northeast possessed potential resources of biomass materials,

such as agricultural and animal wastes, for energy conversion; the North had both water resources and topography suitable for microhydroelectricity, and trees to be used in charcoal production; and the Central plains were good for cultivation of lowland crops. These findings were useful for the general planning of types of energy systems to be introduced in each region.

Complicating the evaluation of the benefits of the Village Survey component, however, is the fact that political criteria often determined the selection of many of the sites for project implementation, rather than the results of the surveys.

The main data from the National Baseline Surveys were analyzed by the contractor in two stages. Stage one was the preliminary presentation of data in a fourteen-volume report.[1] Stage two was a more detailed analysis in a three-volume series prepared as part of the Energy Master Plan component.[2] Subsequent selections of implementation sites were in some of the sampled provinces: Chiang Mai for microhydroelectricity and RECs; Roi Et and Si Sa Ket for woodlots, although not necessarily in the actual villages surveyed; and one sampled village was selected for woodlot implementation. (The Village Woodlot team also conducted a sociological survey involving some 440 interviews in the provinces of Maha Sarakham, Roi Et, Yasothon and Si Sa Ket.)[3]

Although the timing of the additional Baseline Surveys and the main Transition Surveys conducted by the NEA team was originally intended to help establish a basis for site selection and to follow changes associated with project implementation, in most cases the surveys were conducted simultaneously with the installations of the systems. Nevertheless, the survey results were frequently directly helpful to the technology-implementing teams in suggesting desireable changes in the implementation schemes.

Long-term impacts and benefits from the Baseline and Transition Surveys are possible, depending on how the existing data files and reports are utilized.

4. Factors That Helped or Hindered

The conceptualization of the Village Surveys was excellent, as was the design of the instruments to cover topics of importance to the anticipated implementations of the energy systems. Realization of benefits from the surveys could have been significantly improved, however, if there had been greater coordination between the Village Surveys component and the other components. Coordination was inadequate partly because the organization of the other components was delayed, which in turn resulted from the delay in starting the overall project. At the same time, the survey component had to proceed to the field work when the enumerators, who were university students, were available, i.e., during the summer vacation. Furthermore, the inadequate coordination meant that the survey could have been designed in such a way to make its results more useful for the Energy Master Plan.

In addition to inadequate coordination, a further problem with the Village Survey component was the gathering of information (primarily related to agricultural crops) that was not relevant and therefore not subsequently used under the project.

5. Results and Conclusions

One major theme around which the Surveys component was built was the concept of "participation and self-reliance." The assumption was that a newly introduced energy system would be viable only where the villagers participate in its planning and installation, and maintain and operate it themselves. Both the Baseline and Transition Surveys therefore tried to get at data that would indicate degrees of participation and readiness among villagers to operate and maintain the system. This focus of the Surveys proved very useful for selecting some of the sites and monitoring the installations, as well as maintaining the installed energy systems.

The Village Surveys component was expertly conceived, designed, and instrumented. It covered the three important stages of technology introduction: Baseline, Transition, and Evaluation Surveys, although the last one was not carried out. The problem of coordination, both within the component as well as between this component and the others, is largely responsible for having reduced the value of the surveys. Nevertheless, these surveys resulted in a valuable data collection and represent a major accomplishment of this project.

The impacts and benefits from the Village Surveys were evident in the selection of technology for each region, selection of sites in some cases, and assistance to the implementation process in each site. In addition, some results of the surveys were useful for the Energy Master Plan. Future use of the collected data is still possible.

6. Recommendations

NEA should make the data collected in the Baseline Surveys more accessible and available than is presently the case, particularly for use by RECs, NEA planning bodies, other government agencies, and interested researchers and students. NEIC should reorganize, store, and publish the data.

To be able to compare the baseline data with post-experiment data for each pilot project, NEA should conduct an evaluation survey three to five years after the PACD. By that time, changes and impacts of each component will be more observable. Topics to be included in the proposed evaluation survey should reflect those in the Baseline surveys, so as to allow useful comparison.

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E. Microhydroelectricity

1. Background

In designing the Renewable Nonconventional Energy Project, USAID had three goals in mind for the Microhydroelectricity component:

- Assisting up to 10 villages to develop hydropower resources for productive purposes;
- Creating a domestic capacity for production of standard turbine/generator equipment;
- Establishing a technical, administrative, and analytical capacity for planning and implementing development of microhydropower potential in Thailand.

It soon became apparent that ten installations constituted an overly ambitious goal in view of the time, funds, and personnel available, and in the event, four installations were completed by the PACD. Three of the installations - at Kam Pong, Mae Ton Luang, and Huai Pui - were for the electrification of villages, while the fourth (Bo Kaeo) was primarily intended to supply power to a tin-mining operation.

Before construction started, NEA required that each village agree to form a cooperative with equal shares per household to help manage the system. According to regulations of the Ministry of Agriculture and Cooperatives, the establishment of a cooperative meant that at least fifty per cent of the households had agreed to participate in the NEA project. Some of these regulations were modified by NEA, however, to suit the conditions of each project. In all cases, the village cooperatives own forty per cent of the system, based on labor and material contribution. The village share of electricity revenues remained with the village to provide for repair and maintenance, with any funds left over to be used for other village development projects.

2. Achievements

These goals have clearly been achieved in the experience gained with, and the results of, the four installations completed during the project. In addition, however, a fourth and largely unexpected achievement can be credited to this effort - the strengthening of the spirit of cooperation among the villagers who became involved in these projects by their participation in the cooperatives that were formed for the construction, operation, maintenance, and repair of the systems, and for the collection of fees and the application of funds to village development projects.

The evaluation team was able to visit three of the four installations completed under the project, plus one other of similar size, design, and execution. The technical achievements were:

- **Kam Pong** -- (USAID-supported) Consists of a 20-kW pelton turbine coupled to a three-phase, 380-volt, 25-kVA, 50-Hz. generator. The system provides for a second unit of similar characteristics, for a total of 40 kW. Construction started in January 1983 and installation was completed in December 1983. There has been only a one-week outage since, for bearing and shaft repair. The system supplies 118 households, 790 people (there are seven villages in the service area), and the cold-storage unit at a Royal mushroom project nearby that requires 2.2 kW (7 kW peak starting power). Only one operator is needed to operate the system.

- **Mae Ton Luang** -- (USAID-supported) Consists of a 35-kW cross-flow turbine coupled to a three-phase, 380-volt, 50-Hz generator (est. 40 kVA). Construction started in April 1983, and installation was completed in June 1984. The system serves 125 households, 392 people (three villages are in the service area), and has two operators.

- **Huai Pui** -- (USAID-supported) Consists of a 50-kW cross-flow turbine coupled to a three-phase, 380-volt, 50-kW, 50-Hz generator. Construction started in May 1983, and installation was completed in June 1984. Power generated serves 700 households (there are seven villages in the service area), and the system has three operators and one secretary. (Note: The village headman from Ban Pa Taeng stated that 700 households, participated in the seven villages served. The 1984 NEA report [1], however, gives the seven villages as having 1,094 households, with a population of 4,261. The difference, while not clearly ascertained, is likely to be the households that chose not to participate.)

[The team also visited Pang Bong, which was not constructed under this project. It consists of a 12-kW cross-flow turbine with associated diversion weir and headrace. Construction was completed in 1983. It serves 39 households in six villages (population 149) and has two operators.]

The fourth USAID-supported installation, which the evaluation team was not able to visit because of weather conditions, is at Bo Kaeo, where two 100-kW turbines supplied power for a tin-mining operation (that ceased operation shortly after the installation of the hydroelectric system), and incidentally to four villages of 226 households, with a population of 1,723.

All of these systems except Bo Kaeo were constructed by volunteer village labor, and are operated intermittently, generally only through the night. Variations seemed to be from the period 16:00 to 08:00, to the period 18:00 to 12:00, as in the case of Huai Pui.

NEA's three major economic objectives for installing microhydroelectricity in remote regions were: (1) fostering local participation and long-term financial responsibility for energy systems; (2) reducing operation and maintenance costs for these systems; and (3) creating an indigenous microhydraulic-turbine/generator manufacturing base for future export to the Asia-Pacific region. All these objectives have been extremely successfully met. In addition, households have saved fuel expenses, foreign-exchange savings have been realized, development funds have been created, and financial cooperation skills in the villages have increased.

3. Impacts and Benefits

Social: In all of the villages visited, the electricity supplied by the microhydroelectric installations is being used to operate lights (displacing kerosene), for cooking (rice), and to operate radios and television sets (displacing battery charging). Electric-powered wood-working equipment is now being used in the villages supplied by the Kam Pong and Huai Pui installations, and the latter supplies vaccine refrigeration for two clinics that serve the seven villages. In addition, a cold-storage unit that is used at a Royal mushroom-growing project near Kam Pong is also powered by the system. Villagers using electricity from the Huai Pui system also benefit from the use of several individual domestic refrigerators and a communally owned electric pump that supplies drinking water from a well. Furthermore, their cooperative has installed a public address system to facilitate announcements by the village headman.

In all cases, women have played a significant role in the process, from supplying up to fifty per cent of the labor, to membership in the cooperative councils.

Institutional: The initiation of Thailand's microhydroelectric (and minihydroelectric) systems predates (1963) the activity under the Renewable Nonconventional Energy Project. Nevertheless, the USAID-supported effort is certainly responsible for a surge in both the number of these systems and the rate at which they are being built. From the AID perspective, the Micro/Mini Hydroelectric Project (493-0324) owes its genesis to the design and initiation of the Renewable Nonconventional Energy Project. From the perspective of the NEA engineering staff, the situation has changed from one of annual budgets insufficient to permit the construction of all the systems requested, as it was before the USAID-supported project, to one where budgets are now increased to provide for a larger number of systems than the staff has requested. (For FY 86, the NEA headquarters staff in Chiang Mai requested funds for five microhydroelectric systems and received funds for ten.) The track record of results under this project is credited for having played a role in recognition by the RTG of the economic and social benefits of these systems.

Environmental: Aside from the temporary disturbance to the environment caused by the construction of the diversion weir, headrace, and penstock, the adverse environmental impact of these systems has been minimal. Since no dam and water storage are involved (these are essentially

"run-of-the-river" systems), downstream water flow has not been affected - except for the region from the weir to the powerhouse, where the river flow is diminished by the amount diverted, and that only during operation of the system. The permanent visible civil works - only the weir, powerhouse, and access road, in most cases - have not significantly affected the environment. One beneficial environmental consequence of the Huai Pui project, for example, has been the use of the tail water for irrigating vegetable crops in fields that are downstream of the powerhouse and above the river level.

Economic: The provision of rural electrification by the government is rarely financially cost-effective, in that revenues seldom totally cover costs. Typically, it is undertaken to improve social welfare while also minimizing costs, as in the case of these microhydro electric systems. Five major economic findings from the four projects, which affect the national welfare, are listed below.

- Financial feasibility -- The financial criterion for public-sector investment has been to minimize costs by selecting the least-cost option. In a 1981 financial feasibility study, NEA estimated the energy-production costs of microhydroelectric units and diesel generators to be Baht 1.66 (US$0.07) and Baht 2.82 (US$0.12) per kWh, respectively. At that time, extension of the grid to remote villages had been decided against as too costly, ranging as it does from 200,000 to 300,000 Baht/km (US $10,000 to 15,000/km), depending on site conditions. After choosing three sites, NEA began construction of the microhydroelectric units in 1983. At that time, no in-depth cost comparisons had been made between microhydroelectric and diesel-electric systems. Rather, those villages were chosen that had requested microhydroelectric units and had adequate water supplies. Based upon a mix of actual and estimated average annual costs, the final NEA report for the microhydroelectric systems calculated benefit-cost ratios for microhydroelectricity compared to diesel-generated electricity of more than 1.8:1 for all village projects and 3.6:1 for the Bo Kaeo project. Table E-1 provides benefit-cost ratios in terms of discounted cash flows. (See Annex 3 for spreadsheets, based on NEA's financial data.) Microhydroelectricity is always more competitive than diesel electricity.

- Economic feasibility -- Besides the positive net financial benefits to the government from these microhydroelectric systems, the village-lighting projects had important economic and social-welfare impacts. Unfortunately, the NEA report [1] did not elaborate on such costs and benefits in their economic sections. For example, the villagers' contributions in kind to building and maintaining the microhydroelectric installations were omitted. At each site, villagers contributed labor and most of the materials for construction and infrastructure, saving NEA substantial costs in view of the terrain and climatic conditions. Since such in-kind data existed only for Kam Pong (23 per cent of total costs, in-kind plus cash), an average - perhaps conservative - 25-per cent factor is used for Mae Ton Luang and Huai Pui. Although the village labor

contribution should be shadow valued, data on total labor value and sizes of the labor force for construction were not available. Since NEA attempted to start construction in the off season, when agriculture work was lagging, one can hope such opportunity costs were not high. On diesel-fuel savings, NEA figures did not account for mechanical unreliability of diesel installations, which at some remote sites should require the installation of a second, back-up generator. With these social costs and benefits taken into account, microhydroelectricity still is far more attractive than diesel-electric generation (Table E-1).

- **Foreign-exchange savings** -- Total discounted foreign-exchange savings in terms of displaced diesel fuel over the project life (20 years) are 3,238,000 Baht, 3,718,000 Baht, and 5,301,000 Baht for Kam Pong, Mae Ton Luang, and Huai Pui, respectively, based upon the actual delivered price for diesel fuel in remote villages (9 to 15 Baht/liter rather than the figure of 6.7 Baht/liter as used by NEA). These numbers are suggestive, in that they are estimates of possible diesel costs. However, in view of the high costs of diesel fuel at these sites, they are indicative of substantial net gains. Putting a premium on local energy diversification is impossible, but nonetheless is important in analysis of rural electrification.

- **Reduction in operations and maintenance (O&M) costs of microhydroelectricity** -- A reduction in O&M costs for microhydroelectric installations was achieved by training local operators and using local manufacturers for equipment and parts.

- **Promotion of local microhydroelectric equipment manufacturers** -- Dependence on locally produced equipment and materials for the major components helped develop such an industry in Thailand. For example, two Thai machine manufacturers in Bangkok now can produce microhydraulic turbines and generators. One company, which has the capacity to build systems up to 2,500 kW, may export microhydraulic turbines and generators to Laos. Also, a local machinery factory in Chiang Mai, which has worked with NEA, supplies microhydraulic-turbine parts for the project, although it has no export capability. As a result, Thailand no longer imports units smaller than 2,500 kW from their former suppliers, Japan and China.

At the village level, both communities and individual households have been affected by the projects. The microhydroelectricity projects have had seven major economic impacts.

- **Kerosene fuel savings** -- Most households depend primarily on agricultural earnings, with chewing tea the primary source of income (Table E-2). (Annual income data for Huai Pui appear quite low.) A conservative estimate of fuel expenditures shows that fuel expenses account for two per cent, one per cent, and seven per cent of annual gross incomes for Kam Pong, Mae Ton Luang, and Huai Pui households, respectively, with lighting costs accounting for approximately two per cent, one per cent, and six per cent of gross income,

respectively. Thus, fuel expenditures appear to be not significant, although lighting is the major cash end use (Table E-3). The substitution of micronydroelectricity for kerosene lighting and diesel-generated or battery-powered electricity created net cash savings for many individual households. According to the evaluation team's limited discussions with household members in the three villages, average household electricity bills ran from 25 to 40 Baht/month (300 to 1,000 Baht/year). In comparison, NEA data from Table E-3 show that annual lighting expenditures for Kam Pong, Mae Ton Luang, and Huai Pui averaged 651 Baht/year, 692 Baht/year, and 362 Baht/year, respectively. Many households appeared, however, to be saving far more than these average NEA figures. Thus, most households probably had fuel cash savings amounting to as much as twice their previous annual fuel bills. Besides these financial benefits, women felt they saved money - certainly the opportunity costs involved in going to market to purchase kerosene.

- Income generation -- Economic gains regarding household-income generation are less visible and have not yet been quantified, but they do, or potentially may, exist. For example, electric lighting has not only improved the quality of light, it has also extended the hours during the evening that households can process chewing tea. As no comparative before and after data exist, the magnitude of this effect is unknown, though it may be small in cash terms. Better-quality lighting had positive real benefits to the processors. Also in the Kam Pong village, as a result of excess capacity at the plant, a cold-storage unit has been installed at the Royal Project's mushroom-growing facility. This cold storage will decrease losses, extend the growing period, and increase household incomes.

- Economic costs from construction -- Possible economic (in-kind) losses to households may have occurred from the use of local materials and labor for construction and implementation of micronydroelectric installations relative to diesel-generated electricity or extension of the grid. Since all households participating in the project agreed to provide one worker per household during construction, this may have resulted in income losses in terms of foregone earnings. In questioning household representatives and NEA staff, the evaluation team noted several aspects of the project approach that were intended to minimize this possibility. First, construction was scheduled during off seasons, although it extended beyond off-season months in Huai Pui. Second, if a household did not want to provide labor, it could pay for a replacement laborer at an average daily rate of 30 to 40 Baht in some villages, or provide a lump-sum payment, for example 3,000 Baht in Kam Pong and Mae Ton Luang (3,500 Baht if paid in installments of 50 Baht/month). Many women (fifty percent of the work force) and some children helped in construction, which suggests their opportunity costs were seen to be the lowest for the household.

- **Net economic gains due to the use of microhydroelectricity rather than diesel- or grid-electric generation** -- While in-kind costs occurred, in net terms (in-kind plus cash) most villagers benefitted from the project. Since cash is a major constraint in these villages, the choice of microhydroelectricity over diesel- or grid-supplied electricity allowed villagers to trade off services in kind for cash. A stand-alone diesel system requires significant cash payments from the village for construction, equipment, fuel, and repairs. From the households' perspective, although the microhydroelectric project involved in-kind costs (labor and materials), they saved significant cash outlays that would have been incurred with a diesel system. For grid extension, villages with low energy demand must pay for forty per cent of the cost of the distribution line from the main transmission line to the village. Since villagers who had the choice chose to go with microhydroelectricity and appeared quite satisfied, the economic and financial benefits apparently outweighed their economic and financial costs.

- **Benefits from electrification** -- The social benefits of higher-quality lighting, and the use of radios, television receivers, and video-casette decks, though not easily quantifiable, were extremely important to the villagers' sense of participation in overall development.

- **Cooperative revenues** -- Although the team was unable to see all records, it was reported that collection rates were quite high (in most cases 100 per cent), which seems true in view of RTG's auditing of cooperative accounts. A simple comparison of expected annual revenues to NEA's (high) projected O&M costs suggests that annual revenues should cover costs (Table E-4). In fact, the systems have experienced to date only minor expenses that were not covered under the warranty, such as in Mae Ton Luang where repairs, costing 6,000 Baht were paid for out of a development fund of 18,000 Baht. Other O&M costs include operators' salaries (from 500 to 1,000 Baht/month/person for two hours work per day), the per-diem expenses of operators who attend the NEA training course at Chiang Mai University, and in some villages the provision of free electricity to cooperative council members (Kam Pong), and operators (Kam Pong and Mae Ton Luang). In all cases, the fund should be able to cover these O&M costs.

As a result of the success of the projects, all villages had experienced other households' or villages' wanting to join their system. In Kam Pong and Mae Ton Luang, possible late membership fees ranged from 2,500 to 3,500 Baht/household. In some villages, payments could be made in a lump sum or installments. These penalties were perceived as a means of compensation for the opportunity costs of the original labor and materials as well as a way to increase the development fund. Where excess electricity-generation capacity exists, as in Kam Pong and Mae Ton Luang, the marginal costs to the cooperative of extension to a new

household or village is quite low. Significant net gains may be realized by the cooperative through extension of the system. If all participants (original and late) benefit equally from cooperative dividends or from any development project, late comers may receive higher individual returns.

In some cases, the money collected by the cooperatives from membership fees, share sales, and user fees (universally Baht 2/kWh, with a Baht 10/month minimum) is accumulating, with no decisions yet as to its use. In other cases, the funds have been used for road improvements in the villages, and in one case (Huai Pui) a portion was spent for roofing for a village library.

- **Income distribution** -- Cooperative members in Kam Pong, Mae Ton Luang and Huai Pui evidently took into consideration a household's capacity to pay and contribute labor. For instance, older residents and poorer households often received concessionary terms, although the detailed extent and nature are unclear. In Huai Pui, where PEA is now extending the grid, the rich are opting to join the grid as they can afford such costs, while the poor families are remaining with the microhydroelectric system. This will diminish the excess demand in Huai Pui, and will result in additional benefits of the microhydroelectric project to the poor.

Finally, it must be noted that one of our interviews elicited the statement that the villagers are well aware of USAID's support, appreciate that support, and feel that it will help "bring prosperity."

Table E-1. Financial and Economic Discounted Cash Flow Analyses for Microhydro versus Diesel Electric Generation(a)

	Financial Baht (1,000)		Economic Baht (1,000)	
	NPV(b)	IRR(c)	NPV(b)	IRR(c)
Kam Pong	3,531	(d)	2,862	0.62
Mae Ton Luang	2.911	(d)	2,371	0.57
Huai Pui	4,212	(d)	3.649	0.74

Notes:

a. Compares diesel-electric savings to microhydroelect costs.
b. Net Present Value (NPV): Assumes 20-year project li and 15-per cent discount rate.
c. Internal Rate of Return (IRR).
d. Internal Rate of Return cannot be given since annua net cash flows are always postive

Table E-2. Household Average Annual Income and Expenditures for Microhydroelectric Projects (Baht/household)

Income Patterns	Kam Pong	Mae Ton Luang	Huai Pui
Gross Income	36,043	60,468	19,092
Expenditures	26,904	52,570	18,859
Net Income	9,139	7,898	233

Source: Reference 1

Table E-3. Village Household Average Annual Fuel Patterns for Microhydroelectric Projects

	Kam Pong		Mae Ton Luang		Huai Pui	
Fuel Use	Quantity	Cost (Baht)	Quantity	Cost (Baht)	Quantity	Cost (Baht)
Kerosene (liters)	69.8	629	76.9	692	34.8	306
Lighting	69.8	629	76.9	692	-	-
Benzene (liters)	34.3	39	-	-	49.6	56.3
Lighting	3.4	4	-	-	-	-
Transport	30.9	35				
Diesel (liters)	2.2	18				
Lighting	2.2	18	-	-	99.8	831
Fuelwood (m^3)						
Chewing Tea	14.0	-	19.3	-	13.8	36
Processing	7.6	-	10.6	-	-	-
Cooking	5.3	-	4.0	-	-	-
Heating	1.1	-	4.7	-	-	-
Charcoal (kg)					190	39

Note: Assumes fuel prices are: Kerosene is 9 Baht/liter, benzene is 11.4 Baht/liter, diesel fuel is 8 Baht/liter, fuelwood is 260 Baht/m^3, and charcoal is 0.2 Baht/kg in 1984 prices. Source: Reference 1.

Table E-4 Estimated Revenues and Operational Costs for Village Microhydroelectric Projects

	Kam Pong	Mae Ton Luang	Huai Pui
Number of Households:	118	230	250
	----------total Baht/yr----------		
Revenue (a)	42,480	82,800	90,000
Costs (b)	65,840	66,068	74,060
Net Revenue	- 23,360	16,732	15,940

Source: Reference 1.

Notes:

a. Assumes average monthly electric bill is 30 Baht/month/household.

b. Based upon NEA's estimate (1984) of 3 per cent of capital expenditures. Kam Pong's data are adjusted to reflect installation of only one 20-kW generator. Note that with installation of the second generator, revenues would probably double, with costs increasing only slightly because the cost of all of the civil works have already been included. Thus, Net Revenue for Kam Pong would very likely be positive.

4. Factors That Helped Or Hindered

It is apparent from the achievements of this project component that the impacts seem uniformly positive. Nevertheless, it is also clear that these benefits could have been somewhat more widespread, through construction of additional microhydroelectricity projects, if the overall project had been organized more swiftly and greater funding and a larger engineering staff had been available. That NEA has benefitted from the experience gained under this project component is shown by its more positive responses to budget requests for such installations.

5. Results and Conclusions

Community participation in construction of these installations, and the community involvement in their management, operation and maintenance, and in handling the funds have combined to foster a spirit of cooperation among the villagers, impart new and valuable skills, and to generate involvement with community development projects.

The development of the cooperatives also appears to have increased villagers' financial skills. A variety of factors had to be discussed and agreed upon throughout the project, such as the establishment of membership fees, costs of shares in the cooperatives, penalties for households or villages that joined after construction, payment of compensation for not contributing labor, and the collection and management of electricity revenues.

The three village electricity projects discussed have had very positive net economic benefits. (Unfortunately, the potential industrial benefits of the Bo Kaeo project were never realized because the mine closed shortly after the installation was completed.) The economic impacts of microhydroelectric installations in the North primarily affected two groups the government or public sector and the individual villager or community. The national gains have been the creation of more financially self-reliant energy systems, development of a local microhydroelectric manufacturing base with export potential, and electrification of areas that would otherwise not have received electricity for several years. At the village level, households have benefitted in terms of fuel savings, limited income generation, and the development fund, but they also incurred high in-kind costs. Impacts could be enhanced in future projects through concurrent promotion of industrial use with village electrification. While the villages use only a small percentage of Thailand's total energy demand, the positive economic feasibility and village-level benefits of such rural projects are important in view of a ten-per cent growth in household electricity demand projected by the World Bank.[2]

A unique component of the microhydroelectric schemes was the formation of village cooperatives to construct, administer, and maintain the projects. In addition to the social gains mentioned, positive economic impacts on the community attributable to these cooperatives appear to be the establishment of a village development fund from electricity revenues, increased community financial and entrepreneurial awareness and planning, and concessions for individual income-level constraints.

In summary, total national and village benefits appear to be quite positive at present. Indeed, these conclusions are supported by the RTG, since microhydroelectric projects account for fifty per cent of NEA's renewable-energy budget going to field implementation in FY 1987. NEA hopes to construct ten new projects per year.

In view of high expected growth rates for rural electricity demand (estimated at 7 to 8 percent per annum between 1984 and 1991 by NEA, and higher by the World Bank), and an increasing scarcity of indigenous, nonrenewable fuels such as natural gas and lignite [2], appropriate microhydroelectricity investments appear to be an important component in Thailand's rural energy future.

6. Recommendations

A limiting factor to more financially efficient use of these systems is PEA's policy regarding arrangements for selling excess electricity back to the grid. Presently, if the grid comes near villages with microhydroelectric installations, no set rules exist to sell the excess supply to PEA. Although NEA and PEA are aware of this situation and apparently are discussing the issues, unclear policies limit the national and private economic benefits that could be gained through more flexible private electricity-generation policies. NEA should clarify these policies to permit sell-back arrangements for excess electricity to encourage private-sector investments, which appear

non-existent at present. Also, NEA should promote rural industries for electrified villages to increase income-generation benefits and general productivity of rural areas.

Although collection rates for the users of the cooperative microhydroelectricity installations seem to be satisfactory (100 per cent as reported), the Ministry of Agriculture and Cooperatives should devise a more appropriate form of financial accounting. It should be simpler, more straightforward, and more easily understood by the villagers. In addition, the Ministry should provide practical training to the treasurer/accountants of the cooperatives to help prevent errors and mistakes that might lead to disputes among the members.

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F. Water Lifting Technology

The purpose of this component was to demonstrate and test the feasibility of the use of wind energy, biogas energy, and solar-electric (photovoltaic) energy to pump the required water. It was based on the desirability of low-lift pumping from the water table, which is a meter or so below the level of the cropland in many parts of Thailand. The project paper noted that, "This water can be used to help avoid the effect of delayed rains, monsoon drought and premature drying of rice fields --- [and] --- expand dry reason irrigation from existing rivers and streams...."[1]. The study designed by NEA added the use of a gasifier-engine/pump system to the planned demonstrations. By the PACD however, field experiments involved only photovoltaic water pumping and windmill water pumping. The evaluation team was able to visit the sites of the windmill experiment and the only operating photovoltaic system.

1. Solar Water Pumping

a. Background

Ban Tha Yiam:

A 700-watt solar water-pumping system was installed in the village Ban Tha Yiam, in Sakon Nakhon Province, in December 1983. (It was subsequently increased to 840 watts peak). The system was built with volunteer labor, supplied by the villagers, and includes a 10-m^3 storage tank that is connected by pipe to four gravity-fed 1.5 m^3 distribution tanks scattered throughout the village. (Though the system is reported to be equipped with a piston pump, a screw pump is actually being used.) The system supplies water for drinking and cooking to 61 households (about 350 people) from a sealed well 18 meters deep. Prior to the installation of this system, domestic water was obtained from the same well, via a hand pump, and from two other wells situated outside the village in opposite directions - one a half kilometer away and the other at a distance of one kilometer.

The system is shut down about twice a year for repairs to the pump shaft - a problem inherent in the instability of such a long rotating shaft. Repairs are performed by a mechanic from the Maha Sarakham REC, with parts supplied by the REC and labor supplied by the village. Heretofore, the village headman notified the REC of breakdowns by letter, reporting that this has meant a lapse of five days before the arrival of the technician. This period will be shortened in the future, however, since the headman has now been advised to communicate with the REC by telegram from the nearby town. During outages, the village residents return to their former custom of fetching water from the two wells outside the village - without the option of using the village well, which is no longer equipped with a hand pump.

Ban Sukon:

A 4300-watt pumping system was installed in Ban Sukon, a village in Nakhon Ratchasima Province. This system was intended to provide irrigation water from an existing reservoir to supplement water supplied by the District Irrigation Office pumping station, since only about one-third of the village households benefitted from the latter. After the installation of the solar pump, the construction of the irrigation canal was prevented by "some conflicts in land ownership"[2] - apparently, one farmer refused to allow his land to be used for the canal. NEA reports that, as a result, the solar pumping system was removed and is in storage, awaiting an appropriate use.

b. Achievements

In both villages, the systems were installed and proved to be technically feasible. However, only the solar water-pumping system in Ban Tha Yiam was successful in the long run. This system provides clean water, reduced collection time for villagers, and has reduced water shortages in the village. In contrast, no long-term achievements were realized at Ban Sukon because of the lack of social agreement over water distribution and land-use access.

c. Impacts and Benefits

General: - The residents of Ban Tha Yiam are pleased with the solar pumping system because of the improvement it has meant in the quality of their lives. They emphasized that the water is clean now that the well is sealed and protected from surface water. They appreciate the four distribution tanks because it means that there is a water source close to every house. The system permits them to store water for use when the pump is shut off (generally at 16:00). Nevertheless, they understand the need for conserving water. Obviously, the occasional breakdowns enhance their appreciation of this convenient water supply - and "solar energy is free!" as the headman enthusiastically explained.

As for the Ban Sukon installation, the overall impact was decidedly negative. The only benefits to be seen would be the experience gained by NEA in planning and designing the system, and the benefit to future projects by recognition of the importance of ascertaining land ownership and obtaining binding agreements on land-use rights, in advance.

Economic: - In terms of economics, the financial analysis by NEA showed that the benefit-cost ratio for the Ban Tha Yiam system, and (expected) for Ban Sukon, were 0.49:1 and 0.42:1, respectively. In order for the solar systems to break even with a diesel pumping system, NEA calculated that the cost of the solar array plus the motor/pump should fall by 60 to 70 per cent [2], an unreasonable hope in the near term. Thus, from a private or public-sector investment perspective, such water-lifting systems do not make financial sense.

Social: - As mentioned above, villagers in Ban Tha Yiam benefitted from the pumping system in terms of improved water quality and decreased time required for water collection. The water-pumping system stimulated greater cooperation among the villagers and provided more equitable water allocation than the previous system. However, negative social impacts occurred at Ban Sukon as a result of the denial by one farmer of land-access rights for the water-distribution system. This disagreement prevented the community at large from receiving any irrigation benefits.

d. Factors That Helped or Hindered

The major obstacle to acceptance of the Ban Sukon project was the lack of sufficient attention to the sociological problems inherent in the particular situation. In a situation where cooperation was crucial to the installation, the project was doomed to failure without advance commitment to participation by the parties involved.

e. Results and Conclusions

The solar pumping system at Ban Tha Yiam is certainly supplying a service to the villagers that is useful and that improves the quality of their lives. With its low benefit-cost ratio (0.42:1), however, it is doubtful that its cost can be justified, compared to other systems, even in the near future. Its value lies in the lessons learned - technical and sociological - that may be useful if and when the costs of such systems become competitive.

The Ban Sukon attempt provided a valuable lesson in the importance of advance preparation of community participation.

f. Recommendations

The evaluation team recommends only that the RTG not pursue further solar water-pumping systems unless the particular site conditions justify the investment. The **Solar Pumping Field Manual**, originally published by the World Bank with UNDP financing and now available from the Intermediate Technology Development Group in London, would be helpful in determining such justification. Any planned use of the equipment intended for the Ban Sukon project should also be done in this context.

2. **Windmill Water Pumping**

a. Background

As part of the project objective of demonstrating technologies aimed at improving irrigation-water supply for Thai farmers, NEA installed three windmills at Ban Samoh (Tambol Ta-Tong, Amphoe Raman) in Yala Province. Two of the windmills were designed and manufactured by a Bangkok company that

markets windmills in Thailand. The third was designed by the regional representative of Volunteers in Technical Assistance (VITA), who was resident in Bangkok at the time, and fabricated locally. The first two were essentially conventional multiblade horizontal-shaft turbines, one being a 10-ft. diameter "bicycle-wheel" turbine, the other a 14-ft. fan-wheel with a larger number of (and smaller) blades than the standard American-type windmill, which it resembles. Each was coupled to a single-stroke 7.5-cm piston pump with a 7.5-cm stroke, mounted in a dug well with a water table at 4.5 meters depth. The VITA windmill (also a horizontal-shaft machine) was a 6-m diameter [3] (or 4-m, according to the REC representative at the site) multiblade turbine, with 20 bamboo blades, coupled to a ladder pump in a 6-inch PVC pipe that led to a small reservoir. The windmills were installed in 1982 with the help of labor contributed by ten to fifteen villagers, who worked for twelve days carrying the equipment from the road and erecting it.

D. Achievements

The actual achievements of this project component were minimal. In 1984, NEA reported that, "The wind turbine pumping system experienced some problems in maintenance, since most villagers in the project were rather busy -- and so less care was given to the installed windmills."[4] In fact, as far as can be ascertained from interviews at the site, all - or at least some - of the windmills operated for only two years. During that time two crops of watermelon were irrigated and harvested. Some time thereafter, although the sequence is not clear, the windmills ceased to function, and heavy rains during the dry season - when the windmill irrigation would presumably have been needed - delayed the planting for the third crop. This crop was eventually lost. In any event, the windmills were completely inoperative after 1984.

When the evaluation team visited the site, only one of the multiblade windmills was actually there; it was rotating, the pump rod was functioning, but no water was being pumped. (Since the adjacent wells showed an adequate water level, one assumes the pump was not working.) The second multiblade turbine (plus gear box) had been removed, for eventual repair that may or may not take place, leaving only a rusting tower. The VITA-designed windmill and its associated ladder pump were a shambles, some of the blades broken, others missing.

Field interviews showed that, on the whole, the villagers view the project as a government project, really do not want to undertake repairs, and are not interested in reclaiming the land involved, which was not considered useful land in the first place.

C. Impacts and Benefits

The windmill-water lifting experiment in Yala has not had any significant benefits. A temporary economic benefit for the two-year operation of the project came from the watermelons, sweet corn, cucumbers, and string beans that were harvested successfully on land irrigated by the

windmills. The project had apparently been helpful to poorer farmers who had received one to two rai of the irrigated lands. The villagers had not invested in establishing and maintaining the system, however, as it was viewed as a government project. The lack of enthusiasm for investing in repair may also be related to the fact that this land was originally limited to use by the poorer farmers in the community who could not invest in such repairs. The two profitable crops may have represented a windfall. Temporary improvement of the land from irrigation increased the productivity and value of the land. Previously, other government projects, such as grazing-land improvement, had failed due to the lack of participation by the villagers in using the lands for grazing.

d. Factors That Helped or Hindered

It is clear that the poor design of the windmills - and perhaps of the pumps - bears a significant share of the blame for the failure of this project. Such technical design problems, the alternative demands on the NEA, and the location of the site itself compounded the monitoring difficulties for the system. However, the major obstacle to success was the lack of an organized social system for management. Such a system was needed to deal with equitable distribution of water among users, and maintenance and repair of the equipment. Because of his time constraints, the village headman was unable to provide the necessary coordination role for the project.

The location, mix of crops, and land quality of the site also hindered long-term success. Previous government projects on the public land had reportedly failed because of their distance from the village and the poor quality of the soils. Finally, to a more limited degree, the dismal financial realities of the system gave no economic incentives for more village participation and responsibility towards the system. NEA reported a benefit-cost ratio of 0.81:1 for the windmill when compared to a diesel water-pumping system.[5]. Diesel pumps provided by other government agencies appeared to be preferred by the villagers over investing in repairing the windmills.

e. Conclusions

The windmill water-lifting system in Yala province stopped functioning primarily because it lacked a village management system, it needed better integration of appropriate land-use practices, was difficult for NEA to support adequately, and was economically infeasible as a private venture. A cooperative management organization was needed to designate who should look after the system, to handle water distribution, and to provide a maintenance fund. One man volunteered his time to try to make the system successful, but was not paid for his efforts and was unable to organize the users. The water lifted was not equitably distributed to the users - those closer to the well received more than those located far from the water source. Repairs could not be carried out by the villagers, in distinction to the case of the microhydroelectric systems, because there was no collection of revenue from users for a maintenance fund. Also, optimal land use of the

public lands is another issue that affected the project. The water-lifting system should have been more closely integrated with the existing agricultural system of rotating vegetable crops with rice production.

This type of project could benefit from the village-cooperative and self-sufficient design model established in other components such as the microhydroelectricity-generation systems. It is evident that windmill water-lifting systems have their unique technical problems that require either close supervision and local training or highly reliable, relatively self-sufficient designs. The establishment of a cooperative or user management system, as a prerequisite for implementing such a project, would also ensure long-term user support. Close attention to land-use practices and optimal crop mix can increase village participation and income benefits to the users. Finally, economic incentives for continued support by villagers should be carefully designed into the project.

f. Recommendations

Future consideration of windmill water-pumping systems by NEA, or any other RTG agency, should be made in the context of the criteria outlined in the Solar Pumping Field Manual mentioned in the preceding discussion of Solar Water Pumping.

REFERENCES

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2. National Energy Administration, 1984. A Feasibility Study of Water Lifting Technology in Thailand. p. 90. Bangkok: NEA.

3. Ibid., p. 118.

4. National Energy Administration, 1984. Rural Village Surveys in Thailand. p. 142. Bangkok: NEA.

5. National Energy Administration, 1984. A Feasibility Study of Water Lifting Technology in Thailand. Bangkok: NEA.

G. Biomethanation Systems

1. Background

The project design discussed the production and use of biogas from animal wastes (manure) in rural Thailand, noting the resources available, and suggesting the investigation of the potential of community-scale systems. When the project was underway, however, the focus shifted, and in 1983 NEA conducted a feasibility study of biomethanation systems using waste from agro-industries. This component was purely a technical- and financial-feasibility analysis, including some laboratory experiments, and did not include any field implementation.

Two large community-scale digesters were constructed by NEA in 1982 in villages in Roi Et and Si Sa Ket Provinces. Though they were not supported by project funds, funding from the USAID project was used in 1983 to help monitor community acceptance and the impact of these systems. Monitoring teams included NEA staff members and social scientists from Chulalongkorn University Social Research Institute (CUSRI).

Each of the community digesters was 20 m^3 in volume, with administration and constructon costs covered by NEA, while the villagers provided labor and some materials. The gas produced by these digesters, about 0.3 m^3/m^3 digester volume daily, was used only for household lighting for about three hours in the evening.

2. Achievements

Although the two community digesters were built and operated for a time, the NEA and CUSRI monitoring teams found that neither system was in operation within a year after construction was completed.

The study on biomethanation based on industrial waste-water streams was completed before the PACD and was used subsequently as a basis for a further study, as noted in Section 5.

3. Impacts and Benefits

Since both community systems were abandoned, there were no lasting economic, social, or environmental impacts or benefits from this experiment. The information gained by the monitoring teams may prove beneficial in their future professional activities, however.

The study of industrial biomethanation resulted in a further study (Section 5 below).

4. Factors That Helped or Hindered

Though details on the community systems are quite sketchy, discussions with NEA pointed to socio-economic factors rather than technical problems to account for the failure of both systems.

- **Individual effort (opportunity costs) vs. benefits** -- Within six months or so after installation, villagers apparently stopped supplying dung to the plants except when they wanted lighting for special occasions, because daily collection and transport, involving distances up to one kilometer, reportedly represented too much effort for only about three hours of lighting. Thus, individual household benefits (kerosene fuel savings and better-quality lighting) were not sufficient to offset the households' opportunity costs involved in collecting and transporting dung. Most households switched back to kerosene or other lighting alternatives rather than continue operation of the biogas systems.

- **Proximity to electricity grid** -- Proximity to the grid seemed to lead the villagers to believe that grid extension was a near-future possibility. The power line, however, arrived long after the biogas systems were abandoned.

The combination of the costs in terms of effort, limited benefits, and the possibility of future connection to the power grid seems to have persuaded the villagers to wait for an alternative lighting and electrification option.

5. Results and Conclusions

The primary obstacle blocking successful continuation of the community biomethanation project was the conflict between perceived direct costs and benefits and the indirect social costs and benefits of biomethanation systems. This conflict led to a lack of village cooperation in maintaining a functioning system.

Potentially, the use of biogas digesters includes: (a) direct household-fuel and indirect national foreign-exchange savings from the displacement of a nonrenewable energy source; (b) an indigenous resource for imported kerosene; (c) nonpriced social benefits such as improved health through sanitary treatment of waste materials; and (d) the nonquantifiable benefits of better-quality lighting. Such benefits, most of which are not directly received or easily perceived by villagers, were simply outweighed by individual opportunity costs involved in collection time and labor.

The economic section in the NEA study of industrial biomethanation systems consisted of financial analyses, based on U.S. data, comparing costs of expected diesel-fuel savings to estimated costs of capital plus operations and maintenance for biomethanation plants of various sizes. Based on a simple (i.e., nondiscounted) payback period, the feasibility study concluded that a 5,000-m^3 digester was the smallest financially feasible size with an

acceptable payback period below 10 years, assuming a ten-per cent nominal interest rate. Since this analysis was based on theoretical cost-curve data from U.S. systems (both diesel and biomethanation), the results should be viewed as suggestive, at best.

As a consequence of this preliminary study, the Government of Belgium, in 1985, supported a more extensive study of producing biogas from industrial waste water, by the Belgian firm Biotim, in collaboration with NEA. In its report to NEA, Biotim analyzed the technical and economic feasibility of using five waste streams - from tapioca-starch manufacture, fruit canning, pulp and paper processing, and alcohol distillery wastes - to displace up to thirty per cent of the industries' diesel fuel. It should be noted, however, that the financial analysis of each system compared only biogas capital-investment costs to the value of the displaced diesel fuel. This approach suggested that anaerobic processing of alcohol wastes is the most financially attractive option, with a simple payback period of 2.1 years at most. In recalculations made by NEA that corrected for neglected O&M costs of the biomethanation system, the system based on alcohol waste still seemed the most financially attractive option among the five industries. It is not clear, however, that all O&M costs (e.g., cost of disposal of the digested sludge) have yet been taken into account.

As a direct result of this latest study, however, twelve distilleries in Thailand reportedly have expressed to NEA their interest in producing biogas in conjunction with waste-water treatment. According to NEA, Thai Alcohol may agree to pay for the construction of a biomethanation system in collaboration with Biotim. Since high capital-investment costs may make private financing difficult to obtain, indirect subsidies from NEA, in the form of a decreased import tax on equipment and the provision of soft loans for energy investments, may help to encourage installation of these industrial biomethanation systems.

The USAID-supported project thus directly contributed to future work by NEA that may lead, indirectly, to the privatization of biogas-energy production by important industries in Thailand. If successful, biomethanation systems based on industrial waste-water streams may have important private-sector financial benefits as well as positive national economic and environmental impacts.

6. Recommendations

In view of the potential interest on the part of Thai industry in NEA's participation in biomethanation based on distillery wastes, NEA would be prudent to have a disinterested outside expert review the results of the Biotim study before taking further action.

Before any further involvement in community biomethanation system, NEA should ascertain in advance that village cooperation will be sustained, and that the direct and indirect benefits of the system are appreciated by the participants and justify their continued cooperation.

Three separate solar thermal processes were tested under this project, natural-convection cabinet drying, forced-convection hut drying, and solar-assisted curing of tobacco leaves. All systems were demonstration projects and none was commercialized. In the first system, a variety of agricultural products was dried in the solar cabinets to compare production costs and product quality to current market alternatives. The results of the research shed light on several economic aspects of the dryers. The following six findings are the most critical to the issue of adoption of the system by the private sector and its displacement of either non-renewable or wood-derived fuels.

- Relative Costs of Energy Production -- In the final report by KMITT [3], the costs of production for the solar cabinet dryers, using different coverings (glass or plastic) with air heaters, were US$0.025/kWh and $0.032/kWh, respectively. Without air heaters, unit costs fell to US$0.019/kWh and $0.025 for dryers with glass or plastic covers, respectively. In comparison, electricity costs for drying systems were estimated at US$0.075/kWh, which suggested electric drying was up to three times more expensive than solar drying. In reality, most commercial producers do not use electricity; instead, they simply air-dry the product. Thus, the comparison should be between air and solar drying, for those crops for which air drying is acceptable.

- Investment Costs -- The initial costs of the solar drying system were simply too high for most producers to give serious consideration to investing in solar dryers as compared to simple air drying. For example, cabinet dryers with glass covers cost over 4,000 Baht [3], whereas a producer using air drying only invests in trays and a frame, usually costing less than 1,000 Baht. Since production of several products was highly seasonal, lasting only two to four months, low utilization rates existed. Combined with the high investment costs, this created high unit costs, which added to the infeasibility of the systems. As mentioned below, recent research on multiple-product dryers should help to increase utilization rates and possibly decrease unit costs.

- Product Mix and Quality -- The researchers determined that single-product dryers were too expensive. Current research after USAID funding ended has concentrated on using a mix of high-return products, such as peanuts or soybeans, with other crops. Presently, this research is being carried out by KMITT with Australian assistance. As it is in the initial stages, cost data do not exist. Regarding product quality, the producers did not report any significant increase in quality with the solar dryers. In fact, some users did not appear to care for the quality of the dried bananas using the solar dryers.[4] A social benefit of solar drying is improved sanitation of the product, particularly for dried fish, where DDT reportedly is used by some producers. However, such benefits cannot be easily captured by the investor through price discrimination. The KMITT team felt that if tighter product-qualtity standards existed, solar dryers could be a competitve option for

producers. Also if product sanitation improved, a larger export market for dried meats and vegetables might exist in Asia.

- **Scale Economies and Product Type** -- Large producers were apparently the most interested group of possible investors. For example, Bangkok vegetable growers and some food processing factories had expressed interest in the dryers. As a result, researchers were designing larger solar dryers. This shift in production size probably reflects the ability of larger producers, in contrast to small producers, to finance the high investment costs but does not necessarily reflect decreases in unit costs.

- **Income Distribution Effects** -- At present, dried-food producers cover a range of income levels and sizes of operation. As noted above, current financial constraints of these systems favor larger producers. If tighter health controls were enforced, the smaller producers would probably lose the most relative to other producers.

- **Commercialization** -- Because of the high investment costs, few producers invested in these systems. However, the researchers reported that some large-scale vegetable producers near Bangkok, and food-processing factories producing papayas, longans, and chrysanthemum tea, were intereseted in the systems.

Similar to natural-convection cabinet dryers, forced-air convection dryers were not commercially viable. These dryers were used to dry rice but their high initial costs, short seasonal use (two to four months in most regions), and limited improvement in product quality (ten per cent price increase) resulted in marginal financial benefits to the farmer. These benefits are offset at present by the high investment costs and required changes at the mills in labor skills and use. Currently, KMITT is working with Australian assistance on larger forced-air dryers that combine storage with drying and increase the number of crops processed.

The solar-assisted tobacco-curing component also was not commercially viable compared to alternative energy sources. As mentioned in the technology section, the system displaced about twenty-five per cent of the energy requirements for an LPG system. This is one of the most expensive fuels presently used for drying tobacco. In view of the reported energy costs for different fuels (Table H-1), the solar-assisted system simply could not compete with cheaper alternatives such as fuelwood or lignite. These relative market prices, though, do not reflect actual scarcity values for fuelwood or the environmental costs associated with lignite use, such as land reclamation and air pollution. However, unless such costs are internalized into the market through environmental protection and enforcement, a solar-LPG system cannot compete with current alternatives, despite the important social benefits.

Table H-1. Reported Energy Production Costs for Tobacco Curing (Dried Leaf)

Fuel	Baht/kg
LPG, Fuel Oil	12
Solar/LPG	7
Lignite	3 - 4
Fuelwood	2 - 3

4. Factors That Helped or Hindered

The major institutional, or administrative obstacle to the progress of work under this subcomponent was the delay in commencing the work. The lead team at KMITT reported that some two and one-half years passed before funding and final approval of their planned work was received - thus, only one and one-half years were available for actual laboratory and field testing.

In addition, the major obstacle to commercial adoption of the techniques investigated has been the existence of cheaper alternatives for drying products and the lack of enforceable health standards.

5. Results and Conclusions

The solar thermal processes developed with USAID funding were primarily prototypes with a research focus on field testing but not broad dissemination for commercial use. This component successfully provided a better understanding of the economic feasibility and potential marketability of these processes. It did not achieve commercialization of the systems but this was not an original project objective. It did provide institutional knowledge about the financial constraints of the systems. Research into these systems provided insights into the factors to make the systems financially and economically attractive. While these systems could provide important social benefits, often in terms of environmental impacts, no financial incentives exist for the private sector to seriously consider investment in such systems. For these reasons, the solar thermal systems have had no major economic impacts on Thailand because of the lower relative costs of alternative energy systems.

6. Recommendations

Until changes in relative energy prices or environmental policies occur, solar-thermal systems should be encouraged only for industries or areas where they are commercially viable. Also, future research should concentrate on systems whose fuels or input products can successfully compete with other energy systems. Such systems include multiple-product cabinet dryers and solar-assisted curing systems that displace fuelwood or lignite.

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I. BIOMASS GASIFICATION

1. Background

Biomass gasification technologies have been used in various forms for three hundred years.[1] Interest in biomass energy in recent decades is associated with difficulty in obtaining fossil fuels. Application of biomass energy in remote areas for agricultural development or mining industries and for replacing fossil fuels in times of scarcity, such as during the second World War, are most common. Historically, gasification has been skilled-labor intensive and problematic because of difficulties with purifying gasses.

In the wake of dramatic increases in fossil-fuel prices and associated attitudes about fuel scarcity in the 1970's, experimenting with biomass gasification technology that could use locally available resources was included as a component of the Renewable Nonconventional Energy Project in Thailand. The primary fuels considered were wood, charcoal, corn cobs, and rice husks. Other agricultural residues such as corn stalks, bagasse, cotton, cassava stalks, and coconut shells were also of interest because of their abundance.

2. Achievements

A Biomass Gasification Group was formed, with project support, at Chulalongkorn University, suppported by collaboration with researchers at Chiang Mai and Prince of Songkhla Universities. It was established under the project to assess the status of gasification technologies, compare economic feasiblity of the technology, investigate local application of this technology, and design relevant prototype gasifiers reflecting this preliminary research. At the end of the project, twelve gasifiers with capacities of five hundred watts to twenty-five kilowatts under five major gasification system types had been constructed and tested to some degree. Some of these systems were still in development, but others had already been well tested and one had undergone field testing.

Literature review and experimentation were conducted with a focus on fixed-bed technology using wood and charcoal. Fluidized-bed technologies were also compared and gasifiers that had specific applications but did not exist elsewhere were constructed and tested. This research stimulated further design efforts in gasification technology throughout the course of the project.

A useful, well written report was produced under the project.

3. Impacts and Benefits

As a result of the achievements of this component, viable technology choices have been presented for rural energy applications where fossil fuels are expensive, biomass is available, and electricity use is not feasible. Knowledge of the potential for gasifiers in small industrial and individual use is improved by information collected under this component on local case studies and experiences in the Philippines and Brazil. The project has identified priorities for future research and a strategy for implementing technologies through a proposal for a Gasification Technology Development Center. The World Bank has conducted preliminary studies of rice-husk gasifiers in Thailand as part of the UNDP/World Bank Gasifier Monitoring Program and has proposed developing a scope of work for data collection and initial monitoring of these systems to be carried out by NEA.

In the context of reducing fossil-fuel consumption and improving low-cost energy availablity for rural populations, the direct impacts are limited.

4. Factors That Helped or Hindered

This project component established a network of people, including administrative support staff, to design a work plan, implement case-study research, and conduct laboratory and field experimentation. The major obstacle to greater impact of the Biomass Gasification component may have been the starting point for the program. Experience in gasifier research indicated that the most appropriate application of the technology was in specific, and usually private, commercial industries. Adopting a general research workplan made it difficult to maximize the achievements of research for any one application in the time allocated.

5. Results and Conclusions

The gasification component of the project increased awareness of this technology and also established communication between groups working on gasification in the private, academic and government sectors. Experimental data generated from the prototype gasifiers has been collected and analyzed in quality facilities by excellent research methodology which exhibits ingenuity and commitment.

The potential expansion of this technology has been enhanced by the studies conducted under the USAID-supported activity. The gasification component did not contribute significantly to the immediate reduction of fossil-fuel consumption, but contributed to the awareness of the potential of alternatives to conventional power production. This information has not been adequately packaged or promoted to stimulate significant adoption of gasifier technology developed under the project.

In specific industrial applications where biomass is generated as a by-product, or where direct combustion of biomass must be more efficient or regulated, biomass gasification is a good alternative for energy production in Thailand at this time. Because of inexpensive access to electricity through the grid and gasifier operation difficulties, which makes gasoline or diesel fuel worth the extra cost, other applications in small-scale implementation are not yet attractive

6. Recommendations

NEA should consider continuing support for research on fluidized-bed technology to improve the thermal efficiency of rice-husk gasifier systems. More efficient systems would make investment in this equipment more attractive, encourage its use in large rice mills, and, provide an alternative to lignite or firewood to tobacco-curing installations that are in close proximity to a source of rice husks.

NEA should also support research on development of a safe, simple, inexpensive gasifier that improves the combustion efficiency of, and reduces atmospheric pollutants produced by direct combustion of biomass fuels. This research should include economic comparisons of the costs and benefits of gasification relative to improvements in combustion efficiency of direct burning.

Finally NEA should accelerate its discussions with PEA on the issue of permitting excess electricity from co-generation units to be sold to PEA. This would be an incentive to the use of gasifier systems, where appropriate, in large industries with solid biomass-waste streams.

Both these recommendatons fall within the scope of the proposed Gasification Technology Development Center. Therefore, we recommend that NEA give serious consideration to seeking funds to support the establishment of this proposed Center as the locus of the research recommended.

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Introduction to Discussions of Village Woodlots, Improved Charcoal Production, and Improved Cooking Stoves

In the mid 1940's, Thailand was approximately 60 per cent forested. Clearing the forest for agriculture, timber export, and a variety of other industrial activities has reduced this to approximately 20-25 per cent.[1],[2] According to remote sensing information and analysis of RFD data, this is much less in the Northeast (only about 12 per cent), particularly the area referred to as Thung Kula Ronghai (Land of Tears), which is primarily in Roi Et Province.

Three components of the Renewable Nonconventional Energy Project focussed on wood energy: Village Woodlots, Charcoal Production Improvement, and Improved Cooking Stoves. Together, these components provide an integrated approach to alleviating the pressure on natural-forest reserves and other forested areas scattered among villages and between agricultural lands, caused by wood-fuel harvesting. They also have the potential of making charcoal use more efficient and thus less time consuming, more convenient, and cleaner. The successful promulgation and integration of these three approaches should encourage the use of indigenous renewable resources for rural energy needs and inhibit the switch to imported fuels such as kerosene and liquid natural gas.

Total household fuelwood and charcoal demand in the Northeast has been estimated to be more than 10.3 million m^3.[3] At the time of the Project Design, this was estimated to be up to 90 per cent of the wood deman in the region. At the end of the project, NEA estimated total demand throughout the country to be approximately 40 million m^3, representing 75-80 per cent of all uses of wood.[4] Charcoal accounts for approximately 40 per cent of wood-fuel energy consumption, but about 55 per cent of roundwood use for energy. This represents a loss in the conversion of fuelwood to energy that is accepted in return for the conveniences of using charcoal instead of fuelwood. Charcoal use is increasing in relation to fuelwood because of these conveniences.

A conservative estimate of the sustainable supply of round wood for fuel, based on calculations of available forest resources from a number of sources, is 6.3 million m^3. This yield can be expected to decline as the growing stock is reduced and the demand for fuelwood rises in proportion to population increase. Economic status and cultural traditions dictate that wood will continue to be the most widely utilized cooking fuel. There is a gap between potential production of existing forests and demand for fuelwood; other products are in demand in addition to the pressure from agricultural land expansion.

The efficiency of the traditional bucket-type stove (tao ung lo) is approximately 8 to 14 per cent for fuelwood [5],[4] and 20 per cent for charcoal.[4] The stoves are inexpensive and cooking habits have developed around their use. Households in the Northeast have had easy access to fuelwood from land-clearing residues left from expansion of agricultural land to grow kenaf, and from nearby forest reserves. In some areas of the

Northeast this availablity still exists; however, scarcity is evident, especially in the Thung Kula Ronghai area. Travelling further to get wood consumes time that could be used for working, and might involve not only expense for transportation but also the risk of being arrested for illegal harvesting.

Regardless of the figures used to estimate fuelwood consumption trends, it is apparent that any improvement of the technology of wood-fuel utilization will help reduce pressure on the natural-forest resources used for wood energy. The Village Woodlot component of the project was designed, basically, to address this issue by providing a sustainable supply of wood fuel. The improvement of charcoal kilns and stoves for domestic use also has a beneficial impact on the forest-resource base of any country where fuelwood is a source of energy, in addition to direct advantages to the rural population.

The price of charcoal and the distance people must travel to collect firewood have both been increasing steadily in recent decades. As this trend continues without restocking fuelwood resources, there comes a time when fuelwood problems are acute, when gathering cooking fuel becomes a major task of daily life and consumes a significant portion of household income, through cash outlay or loss of work time. This stage has not yet been reached in Thailand, although forecasts predict it will happen in the next five to ten years.[6],[7],[8] Other sources of cooking fuel, such as LPG and electricity, are still relatively expensive when compared to charcoal and require expensive initial outlays for equipment.

Use of charcoal has increased recently in proportion to fuelwood because of its convenience and the fact that it produces less smoke, although it is more expensive and contains less heating value than the wood from which it is made. LPG stoves are becoming more prevalent in urban areas and where income is higher, which suggests that economics is an important force controlling the choice of cooking fuels. Traditional cooking habits are important considerations in development of alternative cooking technology. Even slight physical changes in devices may influence acceptance. Since grilling is popular, fuels must be compatible with taste. It is likely that in the foreseeable future most of the rural population will continue to use wood in some form for cooking. All of these factors point to the need for more efficient use of wood fuels.

The Improved Cooking Stove component aimed at assessing current stove design and sought to improve the design to raise its thermal efficiency. The Improved Charcoal Production component of the project aimed at assessing current charcoal kilns being used in Thailand, improving on these where possible, and starting a program of promoting new designs and techniques for this equipment through demonstration and training. Like the Village Woodlot component, these components were developed on a good existing research base and provided important information for further development. NEA and RFD also implemented training courses and disseminated the modified stoves and kilns. The production of prototype stoves and kilns that are more efficient than the traditional types attracted private entrepeneurs interested in adapting experience gained from the project to commercial enterprises.

Improved stoves, improved charcoal production, and provision of inexpensive wood through the Village Woodlot concept combine to provide a coherent program for reducing the rate of use of natural forest resources for cooking. Unfortunately, the situation is not that simple. Wood-fuel plantations, as noted in the discussion on village woodlots, are not likely to be able to supply the demand for charcoal; furthermore, these plantations will provide products other than charcoal.

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J. VILLAGE WOODLOT

1. Background

The Village woodlot component focussed on the Northeast, particularly in the Thung Kula Ronghai area of this region, where the soils and climatic conditions are very poor. The soils are saline to the extent that commercial, chemical-grade salt production occurs on open lands in some areas. Precipitation comes in only one season, causing temporary flooding, and the rest of the year is hot, or very hot and dry. This area is also reported to have the highest per capita fuelwood consumption in the country (1.42 m^3/year versus a national average of .445 m^3/year).[1]

Seven tree species were originally considered for use in the woodlots - Leucaena leucocephala, Acacia auriculiformis, A. catechu, Casuarina equisitifolia, C. junghunniana, and Eucalyptus camalduiensis. Eucalyptus camaldulensis, thought by many to be a "wonder tree," was selected for the village-woodlot plantations because of its ability to tolerate the stressed environmental conditions of the targetted area.[3],[4] Also, it grows quickly in the early establishment period, which is important in competition with weeds and for protection against mechanical damage. Furthermore, fast growth is an important feature in demonstrating forestry programs to villagers.

The goal of this project component was to "develop greater institutional capablity 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."[2] The objectives of the Village Woodlot component 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.[2]

Work under this component began with a series of surveys, data collection and analysis, and securing approval for use of public lands. Concurrently, a plan for implementation was formulated based on evaluation of the information being collected.

2. Achievements

The Village Woodlot component of the project was carried out by the Royal Forest Department (RFD) in collaboration with NEA. It established community woodlots in seven provinces in the Northeast, including the Thung Kula Ronghai, most of which is in Roi Et Province. Although reports vary, official count of the area planted between 1981 and 1984 is approximately 5,000 to 6,000 rai (800 to 960 hectares), with about one million seedlings distributed. These were planted in seven Provinces in the Northeast - Kalasin, Khon Kaen, Maha Sarakham, Roi Et, Si Sa Ket, Surin, and Yasothin. The sites selected for planting were predominantly on community-controlled land (about 86 per cent). This land was generally in very poor condition, having been used for sporadic wood-fuel gathering, grazing, or cultivation of some crops by villagers. In addition to the primary focus of establishing plantations on community land, seedlings were also distributed to temples, schools, and private households. Finally, seedlings distributed to individuals were planted along fences, in hedgerows, between rice paddies, and around their houses.

The seedlings in community woodlots were planted by hired labor following a short training workshop on the essentials of establishing a plantation. Trees were planted in woodlots under this project according to the RFD recommendation - two meters apart in rows separated by four meters, so-called 2 x 4 spacing. This is equivalent to 1,250 trees/hectare, or something like 1,200,000 trees.[3] This spacing has the advantage of being able to accomodate intercropping, and in many plantations arrangements were made to allow for this "alley-cropping" agroforestry system. After the trees were planted, weeding and general maintenance were carried out in varying degrees.

In cooperation with NEA, the RFD held eight workshop/training sessions for the Provincial Forest Rangers who acted as planting technicians, and others who assisted in this project. In addition to the field surveys and attitude surveys, an extensive educational and training program was carried out via radio, television, and printed materials.[4]

3. Impacts and Benefits

General: - The major impact of the village-woodlot component of the project is the effect it has had on stimulating tree plantings in Thailand. The 1,200,000 trees planted in woodlots during this project may not seem like much in a nation-wide context. Nevertheless, it is indeed impressive to see forests where none grew before, and rows of tall, slim trees separating paddy fields, along fences, and surrounding village houses, as one drives through the Northeast, North, and Central Regions. It is more impressive when one realizes that these trees are at most four years old.

[There are anecdotal reports from the RFD to the effect that there are approximately 500,000 rai (80,000 hectares) of E. camaldulensis planted in Thailand, on both public and private lands, including the land planted under the project. At least one of those private woodlots was among the

plantings observed by the evaluation team. While some of those plantations are said to pre-date the project, apparently most of them coincide with the onset of this project so that the general uniformity of age is the same.][5],[6]

The Village Woodlot program has been the subject of many interesting socio-economic studies and has stimulated debate among a wide variety of agencies.[7],[8],[9],[10] The experience gained from the activities under this component has been used in developing many new projects. Some notable examples are:

- The FAO has implemented a two-year Regional Wood Energy project that expands on the USAID project results and will use some of the facilities provided under that project.

- The World Bank is considering implementation of a fuelwood-production component of a wood-energy project in the Northeast.

- Donor agencies from the United States (USAID), Australia (ACIAR), Denmark (DANIDA), Sweden (SIDA), Canada (IDRC), Japan (JICA), and the Asian Development Bank and the UNDP (plus several non-government agencies) are all involved in forestry and fuelwood projects in Thailand. These include projects that have direct relationships to the USAID/NEA project, or have research agendas that will further the ongoing activities begun under that project.

- The National Energy Administration of has continued to develop activities begun under this component, in addition to the other wood-energy components of the project. The budget for the Maha Sarakham REC continues to provide funding for growing trees. Furthermore, NEA has held workshops, distributed stoves and seedlings, and is continuing to develop the charcoal-kiln project (q.v.).

- The Royal Forest Department has expanded its research and planting program on fast-growing tree species, including soil studies and agroforestry and management trials.

- Kasetsart University is directly involved with many fuelwood and social-forestry research activities whose development was, to some extent, based on this project. In pursuing these activities, Kasetsart University has been working directly with FAO, ADB, ACIAR, USAID, and the World Bank.

- Private enterprise has used the results of technical studies and the overall experience under this component of the project for further development and direct implementation of the technologies developed under this component.

The woodlots have not contributed to the wood-fuel supply as yet; their establishment, however, has provided villagers with short-term jobs, some training on planting techniques, increased awareness about forestry and conservation issues, and many choices about how to utilize this renewable resource to generate benefits for the community.

Social: - The sociological impacts and benefits are significant and involve changing attitudes, new uses of public lands, and new problems calling for solutions. With this eucalyptus species having an optimum rotation cycle of five years, the older woodlots will soon reach the stage where they should be harvested. The village or tambol councils that have putative jurisdiction over these woodlots, however, are all uncertain not only of ownership and harvesting rights, but of how the trees should be used. These councils are facing a difficult situation that is new to their experience, one that involves ascertaining the right to control, exploring and comparing alternative uses for the trees, deciding on further development of the woodlots, and determining how to distribute any benefits gained. This situation is further complicated by the fact that some villagers are so taken with the wonder of a forest where none grew before - some told the evaluation team that they had never seen a forest before - that they wish to keep the trees undisturbed for their grandchildren.

An additional social impact of the woodlots has been the "regularization" of the use of public lands. In many cases, the community lands planted in woodlots were formerly used by only a few individuals for grazing livestock or growing some crops. This was a productive use, but the land being used in this manner was not available to the rest of the community. The establishment of the village woodlot, by restoring the land to communal use, removed it from this ad hoc activity. There has been concern that villagers who previously used the community land for grazing their animals and growing some crops would be relinquishing a necessary part of their income potential, and that by being planted with trees, the land would no longer be productive. It is not yet clear if this is a valid concern, as no major harvesting has occurred.

Another important aspect is that the eucalyptus plantings on temple and school lands have won the endorsement of these two social institutions. Education programs have been designed around the school woodlots that have involved students in tree planting and maintenance. This has stimulated interest of parents to the extent that they have been requesting seedlings and more information. The temples also have a major educational role and command respect in the community. Both institutions have helped to encourage tree-planting programs and to allay fears villagers have had about the RFD's taking control of local community lands. This part of the program will continue to have benefits into the future.

Finally, it must be noted one of the important benefits of this project component is the shift in the relationship between the RFD and villagers. As a result of the involvement of the RFD and villages in this woodlot activity, the relationship has evolved from being generally adversarial to being much more cooperative. This positive change in the RFD's role and villagers' perception of the RFD is critical to sustainable

forest management.

Environmental: - There has been an aesthetic and environmental improvement to previously marginal land. The trees stabilize soil and provide shade and protection from the wind. There is a reported moderation in microclimate near a school with a small woodlot of its own, but in close proximity to a larger woodlot, located in a particularly flat barren area, as a result of the woodlots there. Some people interviewed expressed a desire to keep their woodlots as public parks, and there is a renewed interest in community land use as a result of the program.

On an individual level, villagers are more conscious of the value of trees as an environmental enhancement. Aside from the new appreciation of a forest that has already been mentioned, there is a trend toward planting trees on their own lands and around their houses. This trend is so strong that one of the RECs reports that eucalyptus seedlings are being stolen from some nurseries - a striking measure of the impact of this project component.

Economic: - In terms of economic impacts, the issue of product choice and end use is important, and certainly will continue to be in future fuelwood-establishment schemes. The choice of Eucalyptus camaldulensis was based on stress-tolerance characteristics, rather than optimal end-use characteristics. While trimmings and by-products of the eucalypts could be used for fuelwood, it is apparent from the team's discussions with villagers that of those who are considering harvesting the trees, most do not plan to use them for fuelwood. Rather, they want to use them for construction (village or commercial sale), charcoal production, or paper pulp. These plans reflect the fact that eucalypts have higher opportunity values than for fuelwood use. For example, wholesale market returns for fuelwood are 225 Baht/m^3, poles sell for 80 Baht/pole and wood for pulp brings 280 to 420 Baht/m^3. Villagers prefer to collect fuelwood from natural forests rather than use their plantings for fuelwood or, perhaps, even charcoal production. Such responses are substantiated by village surveys conducted by CUSRI and the East-West Center, and by FAO.[11],[12]

Private interest is strong, as noted above. At the Regional Energy Centers and Provincial Forestry Offices, the demand for free seedlings by individuals and communities apparently always exceeded the supply. Also, it appears that many households are willing to pay for the seedlings because the Forest Industry Organization sells seedlings and commercial nurseries have developed. Although interviews with owners of private woodlots were limited, such people expressed interest in selling the trees for poles or pulp, and only a few mentioned charcoal production. It is interesting to note that many private plantings appear to have been established and maintained by women.

Since the plantings are still immature, the actual income gains cannot be quantified at present. The project will give the village income or in-kind value if the trees are used. Private income was gained by those who were paid for planting on public lands and also by households that received free seedlings. Positive benefits will also result directly from public-school, wat, and communal plantings. However, many communal-woodlot

schemes displaced the previous users of the public lands who often grew crops or grazed cattle. These people have definitely lost income or in-kind benefits. Some projects tried to compensate for such losses by allowing intercropping for the initial years and later permitted grazing, particularly for lower-income households. School officials interviewed expressed interest in using the wood for charcoal or for developing a fund for a school-lunch program. As there are no income-biased restrictions on obtaining seedlings for private plantings, and no significant financial constraints, the only limitation on the potential benefits derived from private use is the size of landholdings.

4. Factors That Helped or Hindered

The major obstacles to realization of economic benefits from the village woodlots has been the failure to identify markets before - and since - the trees were planted, and the uncertainty about ownership and harvesting rights.

The plantations that were established have a rotation age of five to eight years. To date, almost five years after planting many stands, there has been no management plan developed for the stands. Before they were planted, there was no significant market analysis for eucalyptus and there was little consultation with villagers about the purpose of the plantations. No extension program was effectively associated with the project. No thinning has been done. These factors have severely reduced the impact of the program.

5. Results and Conclusions

Eucalyptus species have been recommended for many areas of Thailand, and now they can be seen growing in small stands such as village woodlots, as hedge rows and fences, between rice paddies, and randomly planted in home gardens.

Initially, it appears that proliferation of eucalyptus will surely reduce pressure on natural-forest reserves and provide accessible good-quality fuelwood for the rural population. On closer inspection, however, it is apparent that standard silvicultural systems for eucalyptus, which would inherently provide a continuous source of fuelwood and other products, are not being followed. Removal of poor stems, or thinning in any form is not apparent. In fact, it appears that there is as yet no use of eucalyptus for fuel anywhere in Thailand. Some villagers who were interviewed regarded the woodlot trees as a preserve because the RFD planted them, and they were reluctant to cut them. Instead, they continue to gather wood for all purposes illegally from the forest reserves, or from remnants of the natural forest that remain interspersed in the paddy. The trees planted in individual gardens and along paddy dikes were considered as ornamental.

Village-woodlot planting has been shown to be technically feasible. Examples of interest in the wood-energy component results are encouraging and many plantations are growing well. In addition to the woodlots planted directly under the project, eucalyptus seedlings have been planted at a rapid rate throughout the country under other related projects and independent enterprises.

Continuation of the work begun under the project is necessary if the experience gained is to have an impact on trends in natural-resource utilization. At this time, technology is available to introduce innovative and comprehensive wood-energy programs in each of the regions in Thailand. Each region and, in fact, each village, has unique economic and social requirements. Adaptations of technology can easily contribute to these requirements.

Research has surpassed implementation of research results to a point where political, legal, and social factors have become critical aspects of achieving the objectives of alternative-energy development with fuelwood plantations. Therefore a concerted effort to disseminate and preserve the knowledge gained through the project is necessary, by involving villagers, entrepeneurs, and administrators in the practical implementation of the results of this research. If the concepts are not accepted by the users of wood energy, the technology will not be efficiently utilized.

With optimum conditions, a significant number of stands established under the project will be producing marketable timber in the next one to six years. It is unclear to villagers, village headmen, and tambol council members, however, what should be done with the stands. Furthermore, it is not apparent that either the RFD or NEA has a firm policy on this issue. Market development is lacking and integration of woodlot projects with the charcoal-production improvement and charcoal-stove development activities, which was not adequate during the project, does not seem to have been strengthened.

The project went as far as establishing stands and disseminating seedlings, but adequate training in forest management, basic forestry extension in areas such as harvesting and transportation, and forest-products utilization have not been successfully provided.

The perception among villagers is that eucalyptus will eventually grow to the size of the indigenous dry dipterocarp species if allowed to grow long enough, and that poorly growing stems are the result of poor care and not genetic characteristics. According to village representatives interviewed during this evaluation, the primary markets envisaged for eucalyptus growing in community woodlots do not include fuelwood or charcoal. There is, however, an impression that pulp markets will increase dramatically in the near future and that eucalypts are good for furniture and construction. It should be noted, nevertheless, that other recent studies indicate that charcoal production is also a desired use at the village level.[11],[7],[8],[13]

In general, the perception of temple abbots and teachers involved in the project is more varied than that of villagers or village representatives. Some felt the trees would provide money for community development, either through sales for charcoal production or other forest-product markets. These participants have taken some lead in encouraging their communities to plant trees; the extent of their knowledge, however, is limited and there are misconceptions among these groups about silvicultural prescriptions and market potential for the trees.

6. Recommendations

Subsequent development projects in the use of wood energy can rely on the expertise of Thai researchers, but the institutional support for implementing effective wood-energy development may require the support of private enterprise. Alternatively, establishment of a group specifically organized to integrate social and technical disciplines of forest and energy sciences might be considered.

As eucalyptus stands planted under this and other projects mature, the RFD, in collaboration with the NEA, should take the initiative in exploring markets for this resource. The opportunity to use these trees for a variety of purposes, if well planned, will provide an incentive for rural communities to practice forestry. Forestry is an option for land use like grazing or rice farming. In order to make it worth while, it has to be the best option for the labor required and the land resource. In most cases, land to be used for forestry is not suitable for uses other than grazing. If tree species can be grown on this marginal land with minimum effort and provide useful products, including income and environmental improvements, then forestry will sell itself. At this point, market development is far behind development of the woodlots.

Furthermore, before people can be expected to make rational decisions about the disposition of trees on village woodlots, the land-tenure situation must be clarified. People must feel they have control of their land, even community land, in order to be able to decide for themselves that trees are the best option. In order for this to be the case, not only is market development essential, but land- and tree-ownership questions must be settled, or popular participation in community-woodlot schemes is doomed from the start. The RFD, on behalf of the Government, must take steps to clarify this situation.

The RFD should investigate the use of other species for large-scale planting in Thailand to avoid the dangers inherent in large plantings of a single species. These risks include insect infestation, such as the psylid infestation that has seriously damaged much of the Leucaena leucocephala stock in the Philippines and Indonesia, or attack by pathogenic fungi. Other species of stress-tolerant trees are suitable for planting in villages in the Thung Kula Ronghai region. Where conditions are more favorable, a wide variety of improved indigenous species resistant to local pests and already known in Thailand can be planted. As a source of fuelwood, a tree that pollards well - resprouts easily when the top branches are pruned - might be

better than eucalyptus, since the branches can be used as fuelwood without damaging the tree. There are many nitrogen-fixing trees, such as Leucaena species, that enrich the soil and require less fertilizer, and trees whose shoots, leaves, and flowers can be used as food or animal fodder. In addition to these uses, many trees are much more valuable timber species, albeit slower growing. By the pruning of branches, to be used for fuelwood, the bole (trunk) of the tree becomes more valuable as clear lumber, and sunlight is allowed to reach the forest floor, which provides potential for agroforestry and silvipastoralism (grazing under the trees). There is little incentive to prune Eucalyptus camaldulensis because of its low value as saw timber.

Diversity is a safeguard against market fluctuation and the risk of natural disaster. Intercropping of several species of trees in one stand, or planting different types of stands, provides the opportunity to harvest several products and cultivate others simultaneously. Diverse plantings are more adaptable to intensive management such as that found in typical home-garden systems. Like the natural forest system, mixed cropping also makes more efficient use of light. Some species are shade tolerant and can be established under fast-growing species; when the upper-canopy trees are harvested, the understory will be released for accelerated growth. Finally, different species frequently create different demands on soil nutrients and water at different periods of their life cycles. Therefore, diversity of species places less stress on land resources.

Successful continuation of the village-woodlot component of the project depends on extension services. RFD should endeavor to integrate the activities under its silviculture and land-development divisions to incorporate the recommendations of excellent research results that already exist, into program design and follow-up. In addition, cooperation among RFD, NEA, and the universities would greatly strengthen the forestry sector. For forestry to be properly incorporated into village systems, agroforestry should be included. This implies a coordination of activities of the agriculture, water-resources, and soils-research divisions and subdivisions of RFD, plus socioeconomic disciplines. Furthermore, the work of donor organizations should be coordinated to maximize the usefulness of these projects and avoid unnecessary duplication of resources.

These considerations present options for future woodlots and overall reforestation programs that RFD should consider. Nevertheless, existing eucalyptus stands must be managed for best production and use. Specific recommendations will be found in the annex to this section.

[More detailed discussion and recommendations will be found in Annex 4.]

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K. Charcoal Production Improvement

1. Background

The project design looked to improve charcoal production techniques as a means of reducing charcoal prices, conserving wood supplies, using forest residues and reforestation wastes, and providing an expanded revenue source for rural areas.[1] This project component was begun in April 1982 and, though USAID support terminated at the PACD, continues under the RFD with support from FAO. The project supported the establishment of a Charcoal Research and Training Center in Saraburi Province that is now being used in conjunction with the FAO project.

2. Achievements

According to the NEA's final report,[1] the objectives of this component were to:

- publish a country status report on charcoal production, demand, and supply in Thailand;
- study all charcoal production technologies in Thailand and some from abroad,
- develop improved charcoal kilns and production techniques,
- promote and extend improved charcoal production technologies,
- and increase charcoal research facilities and staff.

This component fulfilled all objectives by the end of the project, except for promotion and extension of the improved kilns. However, NEA and RFD have continued work on charcoal-production improvement since the end of the project and are currently in the process of promoting the improved kilns through the RECs.

In terms of project output, the specific achievements include:

- a substantial survey, conducted by RFD, on charcoal production, distribution, and consumption in Thailand;
- evaluation of thirteen techniques of charcoal production;
- testing and comparing different kilns for charcoal yields and quality;
- improving firing methods and kiln construction;
- nine promotional training programs for 307 trainees from rural-development organizations, villages, and charcoal manufacturers;
- the establishment of the CHarcoal Research Center; and
- three training sessions at the Center, for trainers, on the construction and use of improved kilns.

3. Impacts and Benefits

General: - By the end of the project, there were minimal impacts or rural energy use. The potential beneficial impacts for Thailand were the development of improved production techniques and the collection of better data on the charcoal system. There was limited effect on rural energy use since only a limited amount of kiln promotion and relatively little extension had been conducted by the end of the project.

Technical impacts of this component relate to existing kiln operations and new installations. The Center's research on firing techniques provides scientific information that is correlated to basic indicators of kiln efficiency. These indicators, such as smoke color and chimney temperature, tell the operator what is happening inside the kiln. By controlling temperature and air intake, the operator may monitor the quality and quantity of charcoal being produced and minimize firing time.

Economic: - The economic impacts of improved charcoal-production techniques seem to be minimal at present because of cheaper alternatives available to small producers, and most importantly, the regulations regarding charcoal production. The NEA figures and our field notes suggest that their medium-sized improved kilns (8 and 20 m^3) have payback periods between one and three years, depending on the increases in charcoal production that are realized (five to sixteen per cent). Individual households, however, may not invest in new kilns because present methods and fuel costs are so low. Similarly, large commercial producers using mangrove and rubber trees for charcoal export, as in the South, use larger kilns than NEA models that are similar in design, so that they may have little incentive to adopt these models. Besides these financial considerations, present restrictive charcoal-production laws are the main reason producers may not adopt the technically improved kilns. Some producers may be overcoming these restrictions by obtaining licenses.

4. Factors That Helped or Hindered

The promotion and implementation of the charcoal-production program would have beenhelped significantly by changes in regulations concerning charcoal production. The laws that presently govern charcoal production inhibited the active participation in the project (data collection, development of techniques) by most charcoal-kiln operators since they operate illegally, as the laws now stand. The entire network of charcoal production from harvesting to consumer is subject to illegal activities. This fact seriously impaired the reliability of the RFD charcoal survey and the data collected. Although these laws are important to environmental protection, their existence has reduced the effectiveness of promoting the larger (8- and 20-m^3) kilns designed under the project. The laws governing production and distribution of charcoal are currently under review by RTG in order to promote better charcoal-production methods. Where commercial charcoal production does occur under license, such as the mangrove-wood kilns in the south, kilns quite similar to the USAID-developed kilns are already in use. Thus, the incentives for adoption appear minimal.

5. Results and Conclusions

The charcoal-production component efforts have continued with the support of NEA and FAO. A workshop sponsored by FAO will take place October 27-November 7, 1986 at the Charcoal Research Center established under the project at Saraburi, with attendance by people from throughout Asia. The World Bank is currently considering use of the USAID project results in implementing a fuelwood energy project in Thailand; training courses for over three-hundred participants have encouraged the construction of thirty-four kilns for demonstration; and consulting services provided by NEA continue. Although the commercial-scale kilns might be difficult to adopt, the small (2- and 8-m^3) kilns have application at the household level without hindrance

With continued efforts by NEA, and support from FAO, additional benefits might be realized. Since the end of the project, NEA has developed a computer model for charcoal production costs that allows the determination of fuelwood requirement and necessary plantation size based upon kiln size and charcoal prices. During the project, few data existed at NEA on most factors related to wood-plantation and charcoal-production costs. Data gathered by NEA and RFD under the project, however, have made this model useful to NEA's extension efforts. This model promises to be additionally useful in providing more reliable information to potential charcoal manufacturers. Results from the model clearly show that wood-production cost is the critical factor in positive returns from charcoal production.

6. Recommendations

In order to disseminate the charcoal-kiln technology developed under the project to commercial operators effectively, regulations must be altered to provide a mechanism for legal sales of the charcoal produced. NEA and RFD are aware of this need and discussions on possible changes have occurred. One consideration might be that RFD or NEA issue licenses only to those who produce charcoal in approved kilns and who have fuelwood plantations. This would provide an incentive for using more efficient technologies and sustainable fuelwood management. For village charcoal production, NEA and RFD might consider forming cooperative systems based on the traditional practice where villagers take rice to a mill and pay for milling.

A second critical factor to consider in charcoal-production promotion is the linking of charcoal making with sustainable fuelwood production. NEA and RFD should collaborate to ensure that charcoal-production technology training by NEA's Regional Energy Centers is presented together with information from RFD on growing trees for fuelwood. Commercial production from nearby fuelwood plantations reduces the cost of harvest and transportation, and generally makes more efficient loading of kilns possible because of uniform, straight stems. This coordination of efforts can go both ways; NEA can use RFD support on its charcoal-production extension efforts and RFD can rely on help from NEA at established fuelwood plantations. With this in mind, a demonstration kiln should be set up by NEA near one of the

existing community, wat, and/or school woodlots, fired with thinnings from the trees.

Although NEA has made substantial progress in understanding the system of fuelwood/charcoal production, the team recommends that efforts by NEA receive continued support for its extension of the program to rural areas. Coordination of the fuelwood, kiln, and stove components appears to be the best way of multiplying the benefits of each program and decreasing deforestation pressure from fuelwood. We recommend, therefore, that the NEA and RFD, using the RECs, do a demonstration project using eucalypts for fuel, charcoal kilns designed under the project, and charcoal stoves from a local stove manufacturer using the designs developed under the USAID project. In order to operate a kiln for community use, accurate estimation of potential needs of the village must be obtained, calculations of conversion from available species to charcoal should be made, and equitable arrangements for selling charcoal decided. The involvement of NEA and RFD staff will be essential to training and monitoring producers. Awareness of alternative market values for Eucalyptus versus the price of fuelwood and charcoal on the open market is essential. Information disseminated from the Forest Products Research Division of RFD or the Forest Industry Organization would be beneficial. Replanting new woodlots, intensifying management of existing stands, and incorporating agroforestry alternatives by the RFD is essential as well. The RECs, because of their location and contacts with villagers, could act as the coordinating arm of such efforts.

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L. Cooking Stove Improvement

1. Background

The project paper recognized the important role that cooking fuel plays in Thailand's total energy consumption. As the NEA stated in its report on this project component [1]:

> "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 per cent 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 objectives of this project component were:

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

2. Achievements

The research and development works on improving biomass-fuel cooking stoves was carried out by the RFD in cooperation with the NEA, with dissemination of the new stoves - information on the stoves, training, and the stoves themselves - being primarily the responsibility of the RECs. All of the objectives listed were achieved.

work under this component began in March 1982 and ended at the PACD, the end of October 1984. In that relatively brief period, commercial stoves of traditional design were collected and tested, new stove designs were tested and a prototype selected, the prototype was subjected to detailed testing and improvement, and many prototype stoves were fabricated for training classes. The research was quite sophisticated and demonstrated that, with some basic modifications, the traditional stove can be made more efficient.

The outcome of the development work was a charcoal stove whose heat efficiency was 26 per cent higher than the average commercial traditional model, i.e., for the same heat output to the pot (working results) it used about 78 per cent of the amount of charcoal used by the traditional stove. The wood stove produced by this effort has an efficiency as much as 58 per cent higher than the traditional model. The improved rice-husk stove had twice the efficiency of the average commercial models.

[Note: Analysis of the data reported by NEA (Ref. 1, Table 7.2) indicates there has been some confusion in the efficiencies reported for the new stoves. The data show efficiency of heat use for the various models, which is as much as 34.2 per cent for the new stove. This is to be compared to an average efficiency of heat use of 27 per cent for the traditional, commercial charcoal stove. This is a gain of almost 27 per cent in the efficiency with which the heat from the charcoal is used. Thus, a given weight of charcoal will provide 1.27 times the amount of heat in the new stove that it will in the old stove. Therefore, for the same amount of heat output, one needs use only 1/1.27 or about 78 per cent as much charcoal as needed for the old stove model. The confusion stems from the fact that the 34-per cent figure is often referred to as meaning "more efficient."]

In addition to the "hardware" achievements, nine training and promotion programs on the improved stove were carried out among villagers in various parts of the country before the PACD.

3. Impacts and Benefits

General: - This report would not be complete without noting the excellence of the research and development work performed under this project component. The report submitted to NEA by the RFD team involved in this work contains a wealth of information on the testing and design of charcoal, wood, and rice-husk stoves. The care and detail with which the testing was done, the stove designs which were prepared, and the fabricating machinery and devices that were designed and built constitute a model of scientific and engineering investigation. The devices developed by the team for use by the village manufacturing groups that came into existence as a result of this effort represent appropriate technology at its best.

Although it is too early to say that the improved stove is being accepted all over Thailand, available evidence and the team's observations indicate that this is in the process of happening. It should be noted, however, that this evaluation did not constitute a detailed enough market survey of enough users to provide a firm statistical basis for this opinion.

Social: - One of the benefits of this activity has been the involvement of women in the village groups that have sprung up to manufacture these stoves. Women were the major, if not sole, participants in all of the groups interviewed. Furthermore, since women are mainly responsible for the cooking, they will benefit most in improved health as a result of the more efficient combustion of charcoal in the improved stove model.

The group stove-fabrication activity has provided productive employment to villagers during the period of reduced activity in the rice fields.

Economic: - By the end of the project, the implementation and commercial promotion of improved stoves had only begun. Two years later, there is evidence that the new stove may be gaining popularity and an increasing, though still small, share of the commercial stove market. By the end of the project, most of the information gained was on users' preferences - notably in favor of the charcoal bucket stove and the wood stove (without chimney). With continued effort since 1984 by NEA through the Regional Energy Centers, stove users and stove manufacturers have been trained.

The training of many groups and individuals in fabrication of the improved charcoal stove, and the diffusion of both the skills and the improved charcoal stove to private individuals, commercial manufacturers, and cooperatives shows important economic potential. By training this diverse group of producers, the potential income-generation benefits have been spread to a broader base than would have been the case by concentration only on commercial manufacturers. While the village cooperatives and individual producers expressed the belief that eventually adequate profits will be realized, they have different income and time constraints, thus less flexibility, than commercial producers. For example, such producers find distribution difficult and obviously depend primarily on NEA's purchasing arrangements. Stove production for such producers is highly seasonal - when farming chores do not take priority. It provides part-time work and discretionary income. As was noted above, participation by women and men in the cooperatives or village groups appeared equal, with some groups being made up completely of women.

Besides private individuals or village cooperative groups, the third group of producers, commercial Thai stove manufacturers, are also producing, and in some cases redesigning, the charcoal stove. In particular, one stove manufacturer has invested much time and effort in changing the stove design to lower costs and make production readily available to villagers. Other manufacturers also are changing the bucket and increasing insulation materials to lower total costs. While most stove manufacturers continue to produce traditional stoves, they hope to expand their sales of the improved stoves in the future.

Our discussions with all types of manufacturers indicate that a variety of commercial incentives exists to stimulate expansion. These are:

- Profit margins and cost structures -- In Table L-1, a range of estimated production costs and profit margins is given, based on discussions with four private commercial manufacturers and several cooperatives (or, perhaps more accurately, village groups). The important factor is that the profit margin on traditional (Chinese) models is reportedly only about 1 to 2 Baht/stove as compared to 18 to 31 Baht/stove for the new NEA charcoal stove.

Table L-1. Reported Production Costs, Profit, and Retail Prices for NEA Improved Versus Traditional Charcoal Stoves

Cost Component	Cost (Baht/stove) New	Traditional(a)
Bucket	25	-
Labor	9 - 20	-
Clay liner & Grate	3 - 6	-
Other Material(b)	1	-
Total Production	39 - 52	15 - 16
Profit	18 - 31	1 - 2
NEA Wholesale/Retail	70	
Commercial Wholesale	75 - 85(c)	16 - 16
Commercial Retail	80 - 150(d)	20 - 25

Notes:

a. For chinese model.
b. Includes materials such as rice husk, sand, cement, and/or clay.
c. One commercial manufacturer with an adaptation of the NEA design produced stoves for 100 Baht/stove in 1986, but has a newer 1987 version that can be sold for 85 Baht/stove.
d. High price reflects Bangkok sales.

Relative stove prices and market size -- Although such profit margins favor improved-stove production, the price of the NEA improved stove is over three times the cost of traditional stoves (20 to 25 Baht for the traditional model vs. 70 to 85 Baht for the new model). Thus, sales of traditional stoves vastly outnumber improved-stove sales, making net revenues less for the latter. However, private sales have slowly increased over time, leading commercial producers to be optimistic. Perhaps the price differential appropriately relects actual willingness to pay, in view of better stove quality.

- **Product quality** -- The stove reportedly is significantly better than the traditional model in terms of longer life (one to two years compared to six months to a year), better materials and insulation, and fuel savings (see footnote in the Achievements section). While more experience is needed to confirm this information, both buyers and manufacturers indicated that they believed such advantages exist.

- **Marketing and promotion** -- Most producers interviewed expressed the desire that NEA give attention to more promotion and better marketing arrangements to speed up market diffusion. For small individual producers and village groups, this aspect may be critical to their commercial survival. One manufacturer appeared willing to decrease the profit margin if assured larger guaranteed sales to a commercial wholesaler. NEA's policy to guarantee purchases, and its spreading of quotas among producers, appears to be critical to reducing producers' risk sufficiently for them to decide to enter the market.

4. Factors That Helped or Hindered

As has been noted elsewhere in this report, it is our feeling that more attention to integration of the promotion of improved stoves with the charcoal-production activity and the village woodlots would have helped all three efforts.

5. Results and Conclusions

By the PACD the project had essentially achieved the development of more efficient and socially acceptable stoves. As a result of continued efforts by the RECs and NEA, the stove is being successfully produced by the private sector. NEA has quite effectively and actively transferred stove manufacturing to this sector. Although widespread dissemination has not been achieved to date, and long-term commercialization is not yet assured, the signs are quite positive. The serious efforts by some manufacturers to improve NEA's design suggests strong interest from the private sector in this component. Fuel savings are another major achievement; whether 22 per cent, as the NEA reports, or 50 per cent, as villagers claim, this means users have recovered the higher initial investment costs in the new over the traditional stove in anywhere from two to three months.

Besides encouragement of a commercial improved-stove industry, other indirect benefits of the project are improved labor skills and wages to stove workers. Workers earn about 70 to 100 Baht/day for the new stove as compared to 50 Baht/day for old stoves. Participation by women, regional export of the stoves (to Burma), and its design and fuel savings that may potentially decrease pressure on fuelwood use are other positive impacts. If fuel-use figures are accurate, then the new stove may be the most important component of the project in terms of reducing forest-use pressure. Also, households will save a significant portion of their charcoal expenses.

This component is a highlight of the project. Many achievements have resulted after USAID funding, attesting to the RTG's strong support for and belief in this effort. If the commercialization is successful and widespread, this component will affect a large sector of the rural and urban population.

6. Recommendations

In view of the important commercialization achievements of the stoves development, we strongly recommend that the RTG continue supporting this program. Since the program appears to be at a critical stage, continued RTG and donor-agency budget support is needed, although not necessarily in large amounts. In order for cooperatives, village groups, and other producers to increase their direct sales, NEA should devote attention to developing either more wholesalers or other marketing alternatives. NEA, or the Cooperatives Promotion Department could provide additional assistance to the village groups by helping them with accounting methods. Stove promotion through related RTG projects, such as the Accelerated Rural Development project, community development, and RFD seedling-distribution centers is needed. This could easily and rapidly increase public awareness at minimal costs to the government. With eighty per cent of Thailand (the rural population) dependent on cooking stoves, this program could be highly successful in terms of individual user, producer, and national benefits.

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M. Solar/Wind Resources Assessment

1. Background

This project component aimed at providing assistance to the RTG in evaluating the potential for exploitation of Thailand's solar- and wind-energy resources. USAID support was to "provide the foundation for sound technical, economic and social decisions."[1]

The implementing agency for this component was the Meteorological Department of Thailand (MET). The objectives were:[1]

- to establish a Center for Solar Radiation and Wind Calibration with capability of continual measurement and calibration and maintenance of the necessary instruments; and
- to evaluate the data collected to determine the potential engineering usefulness of solar and wind energy.

2. Achievements

After a resource-assessment plan for solar and wind energy was developed, the Center for Solar and Wind Calibration was established at the Bang Na Meteorological Office, about ten kilometers from the MET head office. With technical assistance under the project, instruments were specified, purchased, set up, and calibrated. Ten stations were established for wind measurement, and six for solar radiation. (See Ref. 1 for location of individual stations.) These stations are equipped for continuous recording of individual data points and integrated values, and are continuing to supply data.

Under the project, a training course was given to government officials from MET, the Department of Science Service, Electricity Generating Authority of Thailand (EGAT), and NEA. Also attending were representatives from KMITT and the Thailand Institute of Scientific and Technological Research (TISTR), with observers from MET, KMITT, and AIT.[2] This type of training has continued since the PACD. The data collected under the project were processed and analyzed at KMITT and AIT, and the results made available in two publications.[3],[4]

3. Impacts and Benefits

Since work on the solar- and wind-energy assessment did not begin until some time in 1983,[5] it is not clear if the results of the measurements played a role in the selection of sites for the photovoltaic and windmill water-lifting systems. The data collected, however, are a valuable addition to Thailand's information base on its meteorological characteristics. They will no doubt contribute to future decisions regarding siting of systems to exploit solar and wind energy and to analyses of weather conditions in Thailand.

The establishment of the Center for Solar Radiation and Wind Calibration has made available to the Meteorology Department and other organizations in Thailand an institutional base for standardization of instrumental measurements, which will make future data collections more reliable.

4. Factors That Helped or Hindered

There is no doubt that technical assistance provided under this project was instrumental in assuring that the Center was properly equipped and in helping to set up calibration techniques and data-analysis procedures. Temporary datalogger problems, however, caused some delay in data collection and analysis. Finally, limitations in funding and in staff positions are reported to have hampered the Center's activities, and to continue to do so.[5]

5. Results and Conclusions

The Solar/Wind Resource Assessment component represents a successful undertaking to improve the meteorological analysis capability of Thailand. It has established a new and modern system of measurement, data recording, and data analysis that is capable of generating information on solar- and wind-energy resources that is needed for future energy planning in Thailand. In addition, the information is and will continue to be useful to other sectors, such as the maritime and construction industries and agriculture.

6. Recommendations

NEA should continue to review budget requests of MET on behalf of the Center, to insure that the staff and data-collection and analysis capabilities remain adequate to meet the national needs.

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N. Pyrolysis of Rice Husks

1. Background

The objectives of this component were to study existing literature and examples of pyrolysis technology, determine application of this technology (including socioeconomic evaluation) and formulate a plan for promoting pyrolysis of agricultural residues, particularly rice husks.

2. Achievements

Under a contract with the Thailand Institute of Scientific and Technological Research (TISTR), NEA supported a study of energy use in rice mills and the potential market for rice-husk char briquette. TISTR designed and built two experimental pyrolyzers that provided valuable data, and designed a system that could help meet the energy needs of small to medium-size rice mills.

3. Impacts and Benefits

General: - The research resulted in gas-purification designs that have been adopted by gasifier manufacturers in Thailand. Furthermore, technical support by the Energy Research Division of TISTR has produced both an analysis of pyrolysis and experience in construction techniques that are applicable to a wide range of energy-technology research.

Economic: - In terms of alternative options, pyrolytic systems are simply more expensive or operationally more complicated that alternatives such as gasifiers and diesel generators. TISTR showed positive financial gains (IRR = 57 per cent) for coupling a pyrolyzer with a diesel-fuel system. However, the rice millers converted back to all diesel at the end of the project. This suggests the opportunity costs of a combined pyrolysis/diesel system are too high.

The charred rice husks produced from pyrolysis were formed into charcoal briquettes. However, the quality of these by-products was inferior to charcoal produced by a far less complicated and cheaper rice-husk briquetting method also developed by TISTR. From the rice miller's perspective, investing in the simpler briquetting equipment has a shorter payback period than investing in pyrolysis. It was reported that several rice mills and sawmills have invested in such biquetting equipment, so the commercial adoption of such systems appears to be a more attractive method of rice waste disposal than pyrolysis.

Because of the high technical skills required for operating and maintaining the system, rice millers did not want to spare their workers for training and operating such systems. Also, high labor demands during the rice processing season limited the time available for operating the systems. It apparently is an opportunity cost issue, i.e., the millers simply feel the

benefits do not warrant the opportunity costs given other alternatives for energy and use of rice by-products.

4. Factors That Helped or Hindered

Although this component's objectives were achieved, in that the studies were performed and the design accomplished, the hoped-for impact did not materialize. The complex pyrolysis process requires many steps that should be attended to by one skilled laborer and one or two helpers. Rice prices were depressed during the years that the project was in progress, making it difficult for mill owners to afford capital investments. Finally, although the studies showed a net financial benefit from the savings in diesel fuel, the revenue was not sufficient from the point of view of the rice-mill owners to justify both the investment in this complex equipment and the diversion of the labor needed to operate it - the opportunity costs of the labor were too great.

5. Results and Conclusions

The project demonstrated the actual costs of pyrolysis and provided knowledge regarding key factors related to successful commercialization. Research on briquetting methods, made concurrently by TISTR with other funding, showed such methods were commercially superior to rice pyrolysis by-products.

Pyrolysis systems, although financially attractive when compared to oil systems, at present are not commercially acceptable. Thus, this component has had and will probably not have any direct economic impacts other than pointing to alternative, less costly methods of waste use. Furthermore it is the opinion of both TISTR and this evaluation team that the much simpler gasification process is to be preferred for conversion of rice husks, particularly since use for the pyrolytic oils has not yet been determined, and the pyrolytic char is not as useful in briquette form as briquettes made from rice husk directly.

6. Recommendations

Continued support of pyrolysis projects is not recommended if the objective is commercialization. Other cheaper and less complex energy systems exist. If research continues, it should focus on reducing equipment and labor costs. To handle waste materials, promotion of the simpler rice or waste briquetting systems appears to be a more commercially viable and socially efficient alternative to pyrolysis.

ANNEX 1

SCOPE OF WORK FOR FINAL EVALUATION

Renewable Nonconventional Energy Project

Project No. 493-0304

SCOPE OF WORK FOR FINAL EVALUATION
Renewable Nonconventional Energy Project
Project No. 493-0304

I. ACTIVITY TO BE EVALUATED:

The Renewable Nonconventional Energy Project was conceived by the Royal Thai Government (RTG) and the United States Agency for Internatonal Development (USAID) with the aim to reduce Thailand's dependency on imported energy resources by developing and introducing alternative energy resources. For RTG implementing Agencies see Section IV WORK STATEMENT.

USAID awarded a five year five million dollar grant to Thailand for the development of renewable nonconventional energy resources with an amount of 3.4 million dollars equivalent from RTG contribution. The project has two complementary and reinforcing themes:

The First: is an institutional development component. This component, having long term implications, incorporates support for four distinct but related activities: (1) assistance in establishing a National Energy Information and Documentation Center and four Regional Energy Centers, (2) assessment of renewable energy sources such as wind and solar, biomass, etc., (3) support of RTG capacity for monitoring of technological changes in rural energy utilization and (4) village and rural energy data collection, development of energy conservation guidelines, staff support and training into the Thai Energy Master Plan Study.

The Second: involves carrying out a series of tests and adaptations of renewable energy technologies, which will be carried on at the same time that the work of institutional and data base development goes forward.

Accordingly, at the end of the project there should coincide a tested selection of rural renewable energy applications as well as the data and institutional base to implement them within the framework of a broader RTG energy policy. The Project Grant was signed on August 16, 1979 and the original project assistance completion date (PACD) was July 1, 1984. However, it was extended for four months. The major activity during the extension period was to complete the brochures, the component's accomplishment reports, and the overall project accomplishment report.

The project underwent an interim evaluation in September 1982 and resulted in reorganizing the Project Coordinator's role and redesigning some project components to focus on research development and village implementation (where possible).

II. PURPOSE OF THE EVALUATION:

The purpose of the evaluation is to assist the RTG and USAID Misson to:

A. assess the achievements of project outputs and measure the degree to which the project purpose and end-of-project-status have been realised.

B. examine the degree to which the technologies and information generated by the project are influencing energy consumption patterns of the people involved, especially the social impact on rural villagers.

C. address what technologies developed under the project have proven to have high potential for commercialization and dissemination and future active roles of already established institutions.

D. assess any environmental and ecological impacts from the adopted project activities.

E. explore both private and public sector activities to determine if development activities are being undertaken and, where undertaken, evaluate the magnitude and quality of the implementing agency's activities. A similar search will be made of private industry and private individuals, to the extent they can be identified, in order to determine how private sector investments are now being made for developing energy applications.

F. make recommendations concerning additional or alternative uses of the information and/or the generation of additional information/activities for possible future applications.

III. BACKGROUND

Energy is a key element in any effective rural development strategy, and this is specifically acknowledged in the Country Development Strategy Statement (CDSS):

"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.

AID proposes assisting the RTG to reduce its dependency on imported energy sources by developing and introducing alternative energy resources.."

The Renewable Nonconventional Energy Project was a product of that Mission strategy.

IV. WORK STATEMENT:

(A) Project Components to be studied:

The evaluation scope of work will cover several components of the Project:

1. National Energy Information Center	National Energy Administration
2. Regional Energy Centers	
3. Energy Master Plan Support	
4. Village Survey	
5. Micro Hydro Technology	
6. Water Lifting Technology	
7. Industrial Biogas	
8. Solar Thermal Processes	King Mongkut's Institute of Technology (KMIT)
9. Biomass Gasification	Chulalongkorn University (CU)
10. Village Woodlots	Royal Forest Department (RFD)
11. Charcoal Improvement	
12. Cooking Stove Improvement	
13. Solar/Wind Resources Assesment	Meteorological Department (MET Dept.)
14. Pyrolysis of Rice Husks	Thailand Institute of Scientific and Technological Research (TISTR)

(B). Key Questions:

In addition to the assessments and examinations listed in Part II Purpose of The Evaluation, following are some illustrative questions to be answered for each of the components listed above.

1. Which are potentially most cost-effective (based on analysis of time, effort and resource requirements of each technology)?

2. Is there evidence of acceptance and utilization, by a well-defined clientele group, without direct subsidies?

3. What components appear to have relatively high development impact in terms of its potential for widespread use, and reduction of Thailand's dependence on fossil fuel.

4. Is the institutional base now in place sufficient to carry on the work of promoting renewable energy technologies in the villages?

5. Are there any identifiable social or ecological problems attached to the various renewable energy technologies?

6. What project benefits are likely to be sustained after donor funding ends?

7. What local institutional capacities (management, technical, financial, provisions for maintenance and the replacement of capital equipment) are being developed to continue project benefits? Will they be in place once donor financing ends? What policy conditions are required to facilitate continued long-term impact?

8. How were the interests and role of women taken into account at the design and appraisal stages? Did their participation or non-participation affect project achievements.

9. Were gender-specific data available or have they been developed since? How has such data been used in goal setting and resource allocation?

10. What are the effects (impacts if available), positive or negative, of the proect concepting women's access to production inputs and markets, division of workloads, income, education and training, role in household and community, and health conditions?

11. Though the initial environmental examination was negative, did experience show that there were impacts during implementation?

The Evaluation Team is to investigate those questions and provide:

i). findings - (facts)

ii). conclusions - (underlying reasons)

iii). recommendations - (how problems may be solved and by whom).

V. METHODS AND PROCEDURES:

1. Review of Project literature -- existing reports, previous evaluation report, monitoring reports, project files, etc. which are available at USAID Office of Engineering and NEA.

2. Bangkok interviews with the project component team leaders, NEA and USAID concerned.

3. Field interviews with chiefs of the regional energy centers, manufacturers, rice mill owners, benefited villagers, etc.

4. Trips to Bangkok CU, KMIT, TISTR, etc. renewable energy demonstration park to observe pilot installations under the project.

5. Trips to rural regions to observe energy facilities under the project.

VI. TEAM COMPOSITION:

Energy Expert:

The candidate should be an American citizen with experience as a USAID evaluation team leader. The team leader will be responsible for assuring that the final report answers each of the questions in this scope of work and meets USAID evaluation report criteria. In addition, the team leader will coordinate activities of the other team members. The Energy Expert's experience should include project management of renewable energy systems, energy technology assessments, environmental impact assessments, power plants, industrial wastes, and energy facility sitings.

Recommendations must be implementable. They should be keyed towards dissemination and promotion of renewable energy activities as well as to developing RTG institutional capacity to perform and sustain energy policy planing and further implementation. The Energy Expert/Team Leader will be contracted for a total of 8 weeks. A PSC is preferable.

Energy Economist:

The candidate should be an American citizen with experience in comparative analyses of investments in energy technologies designed to reduce dependence on imported oil. The Economist will prepare preliminary economic assessments to determine which are potentially most cost-effective. The purpose of the evaluation raised in Section II and IV will also be addressed by the Economist. The Energy Economist will be contracted for a total of 8 weeks. A PSC is preferable.

Social Scientist:

The Social Scientist should be a Thai citizen residing in and with considerable experience in Thailand. The Social Scientist will be expected to visit as many villagers and manufacturers as possible. The recommendations and findings should include an evaluation of the social impact of the technologies of the project activities on the villagers, social benefits, roles of women, etc. and the attitude of the beneficiary villagers towards the renewable energy technologies. The Social Scientist will be contracted for a total of 8 weeks.

VII. REPORTING AND DEBRIFING:

1). After a draft report has been prepared by the team, an Evaluation Summary Part I and Part II will be prepared by the team.

2). The draft report will be submitted to USAID three working days before an oral presentation to USAID.

3). After the oral presentation the team will prepare a final version. 30 copies will be reproduced.

4). The report will follow the format: Findings, Conclusions, Recommendations as described above in para IV (6).

5). Final payment will be contingent upon delivery to USAID of the accepted final report.

6). The Final Report must contain the Scope of Work, a description of the methodology used, and a bibliography of materials consulted.

EVALUATION TEAM SCHEDULE

An illustrative work schedule is listed below:

Week one Bangkok

- review of project literature
- meet with project component team leaders, NEA and USAID concerned.
  (Some pilot activities at CU, KMIT, TISTR, MET Dept., etc. will be visited when the team is there).

Week two Northern field trip (fly to Chiang Mai)

- visit micro hydro. installations (Chiang Mai)
- visit some solar dryers for tobacco, agri-crops (Chiang Mai and Phitsanulok).
- visit Phitsanulok Regional Energy Center

Week three Central field trip (by car)

- visit TISTR pyrolytic converter at a rice mill (Saraburi)
- visit RFD Charcoal Improvement Center. (Saraburi)
- visit Ratchaburi Regional Energy Center and private cooking stoves manufacturers.

Week four Northeast field trip (fly to Khon Kaen)

- visit Maha Sarakham Regional Energy Center.
- visit Woodlot activities in Khon Kaen, Maha Sarakham, Roi Et and Si Saket.
- visit cooking stoves manufacturers in Roi Et (financial support by Australian and German).
- visit solar cell water lifting at Sakon Nakhon.

Week five Bangkok

- review of preliminary findings
- meetings with RTG and USAID officials

Week six Southern field trip (fly to Hat Yai)

- visit gasifier for electricity generation at Hat Yai (Songkhla)
- visit water lifting for irrigation by windmills (Yala)

Week seven Bangkok

- Preparation of final report and submission of draft evaluation report to USAID.

Week eight Bangkok

- completion of final evaluation report and presentation of findings and recommendations to USAID and RTG.

ANNEX 2

IMPACT EVALUATION TEAM MEMBERS

Norman L. Brown, Ph.D. Washington, DC	(Renewable-energy specialist)
Marcia Gowen, Ph.D. East-West Center Honolulu, HA	(Energy Economist)
Chalio Buripakdi, Ph.D Srinakharinwirot University Bangkok	(Sociologist)
Kirtland M. Barker, MFS Winrock International Rosslyn, VA	(Forestry specialist)

ANNEX 3

MICROHYDROELECTRICITY COMPARED TO DIESEL-ELECTRIC GENERATION:

KAM PONG:	ECONOMIC ANALYSIS FINANCIAL ANALYSIS
HUAI PUI:	ECONOMIC ANALYSIS FINANCIAL ANALYSIS
MAE TON LUANG:	ECONOMIC ANALYSIS FINANCIAL ANALYSIS

KAM PONG MICRO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
FINANCIAL ANALYSIS
('1000 Baht, 1984 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	212	695	79	986	857	356	29	37	0	422	367	564	491	491
2	212	695	79	986	745	356	29	37	0	422	319	564	427	917
3	212	695	79	986	648	356	29	37	0	422	277	564	371	1288
4	212	695	79	986	564	356	29	37	0	422	241	564	323	1610
5	212	695	79	986	490	356	29	37	0	422	210	564	280	1891
6	212	695	79	986	426	356	29	37	0	422	182	564	244	2135
7	212	695	79	986	371	356	29	37	0	422	159	564	212	2347
8	212	695	79	986	322	356	29	37	0	422	138	564	184	2531
9	212	695	79	986	280	356	29	37	0	422	120	564	160	2692
10	212	695	79	986	244	356	29	37	0	422	104	564	139	2831
11	212	695	79	986	212	356	29	37	0	422	91	564	121	2952
12	212	695	79	986	184	356	29	37	0	422	79	564	105	3058
13	212	695	79	986	160	356	29	37	0	422	69	564	92	3149
14	212	695	79	986	139	356	29	37	0	422	60	564	80	3229
15	212	695	79	986	121	356	29	37	0	422	52	564	69	3298
16	212	695	79	986	105	356	29	37	0	422	45	564	60	3359
17	212	695	79	986	92	356	29	37	0	422	39	564	52	3411
18	212	695	79	986	80	356	29	37	0	422	34	564	46	3457
19	212	695	79	986	69	356	29	37	0	422	30	564	40	3496
20	212	695	79	986	60	356	29	37	0	422	26	564	34	3531

NPV= 4350
Foreign Exchange Savings

Project NPV= 3531
IRR= ERR

Assumes diesel price 9 Baht/liter, discount rate is 15%.

HUAI PUI MICRO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
ECONOMIC ANALYSIS
('1000 Baht, 1994 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	1689	847	81	2617	2276	2972	20	44	743	3779	3286	-1162	-1010	-1010
2	0	847	81	928	702	0	20	44	0	64	48	864	654	-356
3	0	847	81	928	610	0	20	44	0	64	42	864	568	212
4	0	847	81	928	531	0	20	44	0	64	36	864	494	706
5	0	847	81	928	461	0	20	44	0	64	32	864	430	1136
6	0	847	81	928	401	0	20	44	0	64	27	864	374	1510
7	0	847	81	928	349	0	20	44	0	64	24	864	325	1835
8	0	847	81	928	303	0	20	44	0	64	21	864	283	2117
9	0	847	81	928	264	0	20	44	0	64	18	864	246	2363
10	0	847	81	928	229	0	20	44	0	64	16	864	214	2576
11	0	847	81	928	199	0	20	44	0	64	14	864	186	2762
12	0	847	81	928	173	0	20	44	0	64	12	864	162	2924
13	0	847	81	928	151	0	20	44	0	64	10	864	140	3064
14	0	847	81	928	131	0	20	44	0	64	9	864	122	3186
15	0	847	81	928	114	0	20	44	0	64	8	864	106	3293
16	0	847	81	928	99	0	20	44	0	64	7	864	92	3385
17	0	847	81	928	86	0	20	44	0	64	6	864	80	3465
18	0	847	81	928	75	0	20	44	0	64	5	864	70	3535
19	0	847	81	928	65	0	20	44	0	64	4	864	61	3596
20	0	847	81	928	57	0	20	44	0	64	4	864	53	3649

NPV= 5301
Foreign Exchange Savings

Project NPV= 3649
IRR= 0.74

Assumes diesel 9 Baht/liter, shadow wage factor 0.65%, discount rate is 15%.

HUAI PUI MICRO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
FINANCIAL ANALYSIS
('1000 Baht. 1984 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	217	847	81	1145	996	398	30	44	0	472	410	673	585	585
2	217	847	81	1145	866	398	30	44	0	472	357	673	509	1094
3	217	847	81	1145	753	398	30	44	0	472	310	673	442	1536
4	217	847	81	1145	655	398	30	44	0	472	270	673	385	1921
5	217	847	81	1145	569	398	30	44	0	472	235	673	335	2256
6	217	847	81	1145	495	398	30	44	0	472	204	673	291	2547
7	217	847	81	1145	430	398	30	44	0	472	177	673	253	2800
8	217	847	81	1145	374	398	30	44	0	472	154	673	220	3020
9	217	847	81	1145	325	398	30	44	0	472	134	673	191	3211
10	217	847	81	1145	283	398	30	44	0	472	117	673	166	3377
11	217	847	81	1145	246	398	30	44	0	472	101	673	145	3522
12	217	847	81	1145	214	398	30	44	0	472	88	673	126	3648
13	217	847	81	1145	186	398	30	44	0	472	77	673	109	3757
14	217	847	81	1145	162	398	30	44	0	472	67	673	95	3852
15	217	847	81	1145	141	398	30	44	0	472	58	673	83	3935
16	217	847	81	1145	122	398	30	44	0	472	50	673	72	4007
17	217	847	81	1145	106	398	30	44	0	472	44	673	63	4069
18	217	847	81	1145	93	398	30	44	0	472	38	673	54	4124
19	217	847	81	1145	80	398	30	44	0	472	33	673	47	4171
20	217	847	81	1145	70	398	30	44	0	472	29	673	41	4212

NPV= 5301
Foreign Exchange Savings

Project NPV= 4212
IRR= ERR

Assumes diesel 9 Baht/liter, discount rate is 15%.

MAE TON LUANG MICRO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
ECONOMIC ANALYSIS
('1000 Baht, 1984 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	1532	594	77	2203	1916	2577	16	42	644	3279	2851	-1076	-935	-935
2	0	594	77	671	507	0	16	42	0	58	44	613	464	-471
3	0	594	77	671	441	0	16	42	0	58	38	613	403	-68
4	0	594	77	671	384	0	16	42	0	58	33	613	351	283
5	0	594	77	671	334	0	16	42	0	58	29	613	305	588
6	0	594	77	671	290	0	16	42	0	58	25	613	265	853
7	0	594	77	671	252	0	16	42	0	58	22	613	231	1083
8	0	594	77	671	219	0	16	42	0	58	19	613	201	1284
9	0	594	77	671	191	0	16	42	0	58	16	613	174	1458
10	0	594	77	671	166	0	16	42	0	58	14	613	152	1610
11	0	594	77	671	144	0	16	42	0	58	12	613	132	1742
12	0	594	77	671	125	0	16	42	0	58	11	613	115	1856
13	0	594	77	671	109	0	16	42	0	58	9	613	100	1956
14	0	594	77	671	95	0	16	42	0	58	8	613	87	2043
15	0	594	77	671	82	0	16	42	0	58	7	613	75	2118
16	0	594	77	671	72	0	16	42	0	58	6	613	66	2184
17	0	594	77	671	62	0	16	42	0	58	5	613	57	2241
18	0	594	77	671	54	0	16	42	0	58	5	613	50	2290
19	0	594	77	671	47	0	16	42	0	58	4	613	43	2333
20	0	594	77	671	41	0	16	42	0	58	4	613	37	2371

NPV= 3718
Foreign Exchange Savings

Project NPV= 2371
IRR= 0.57

Assumes diesel 9 Baht/liter, shadow wage factor of 0.65, discount rate is 15%.

MAE TON LUANG MICRO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
FINANCIAL ANALYSIS
('1000 Baht, 1984 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	205	594	77	876	762	345	24	42	0	411	357	465	404	404
2	205	594	77	876	662	345	24	42	0	411	311	465	352	756
3	205	594	77	876	576	345	24	42	0	411	270	465	306	1062
4	205	594	77	876	501	345	24	42	0	411	235	465	266	1328
5	205	594	77	876	436	345	24	42	0	411	204	465	231	1559
6	205	594	77	876	379	345	24	42	0	411	178	465	201	1760
7	205	594	77	876	329	345	24	42	0	411	155	465	175	1935
8	205	594	77	876	286	345	24	42	0	411	134	465	152	2087
9	205	594	77	876	249	345	24	42	0	411	117	465	132	2219
10	205	594	77	876	217	345	24	42	0	411	102	465	115	2334
11	205	594	77	876	188	345	24	42	0	411	88	465	100	2434
12	205	594	77	876	164	345	24	42	0	411	77	465	87	2521
13	205	594	77	876	142	345	24	42	0	411	67	465	76	2596
14	205	594	77	876	124	345	24	42	0	411	58	465	66	2662
15	205	594	77	876	108	345	24	42	0	411	51	465	57	2719
16	205	594	77	876	94	345	24	42	0	411	44	465	50	2769
17	205	594	77	876	81	345	24	42	0	411	38	465	43	2812
18	205	594	77	876	71	345	24	42	0	411	33	465	38	2850
19	205	594	77	876	62	345	24	42	0	411	29	465	33	2882
20	205	594	77	876	54	345	24	42	0	411	25	465	28	2911

NPV= 3718
Foreign exchange Savings

Project NPV= 2911
IRR= ERR

Assumes diesel price 9 Baht/liter, discount rate is 15%.

KAM PONG MIRCO-HYDRO VERSUS DIESEL ELECTRIC GENERATION
ECONOMIC ANALYSIS
('1000 Baht, 1984 prices)

	BENEFITS (DIESEL SAVINGS)					COSTS (MICROHYDRO)								
Year	Cap-ital	Fuel	O&M	Total Ben.	PV Ben.	Cap-ital	Labor	O&M	In-Kind	Total Costs	PV Costs	B-C	PV B-C	Sum PV B-C
1	1582	695	79	2356	2049	2657	19	37	805	3518	3059	-1162	-1010	-1010
2	0	695	79	774	585	0	19	37	0	56	42	718	543	-467
3	0	695	79	774	509	0	19	37	0	56	37	718	472	6
4	0	695	79	774	443	0	19	37	0	56	32	718	411	416
5	0	695	79	774	385	0	19	37	0	56	28	718	357	774
6	0	695	79	774	335	0	19	37	0	56	24	718	311	1084
7	0	695	79	774	291	0	19	37	0	56	21	718	270	1354
8	0	695	79	774	253	0	19	37	0	56	18	718	235	1589
9	0	695	79	774	220	0	19	37	0	56	16	718	204	1793
10	0	695	79	774	191	0	19	37	0	56	14	718	176	1971
11	0	695	79	774	166	0	19	37	0	56	12	718	154	2125
12	0	695	79	774	145	0	19	37	0	56	10	718	134	2260
13	0	695	79	774	126	0	19	37	0	56	9	718	117	2376
14	0	695	79	774	109	0	19	37	0	56	8	718	102	2478
15	0	695	79	774	95	0	19	37	0	56	7	718	88	2566
16	0	695	79	774	83	0	19	37	0	56	6	718	77	2643
17	0	695	79	774	72	0	19	37	0	56	5	718	67	2710
18	0	695	79	774	63	0	19	37	0	56	4	718	58	2768
19	0	695	79	774	54	0	19	37	0	56	4	718	50	2818
20	0	695	79	774	47	0	19	37	0	56	3	718	44	2862

NPV= 4350
Foreign Exchange Savings

Project NPV= 2862
IRR= 0.62

Assumes diesel price 9 Baht/liter, shadow wage factor 0.65, discount rate is 15%.

ANNEX 4

WOODLOT MANAGEMENT

[Note: The following comments are a synthesis of discussions held by Mr. Barker with officials of the Royal Forest Department and with foresters and other individuals from other agencies with experience in Thailand.]

WOODLOT MANAGEMENT

General

There is a perception that eucalyptus has harmful effects on soil. One commonly encountered thought, even among educated professionals, is that the oils of eucalyptus leaves are poisonous; another is that they are allelopathic, i.e., produce chemicals that inhibit or prevent growth of other species; and a third is that they make the soil sour, or acidify the soil. These perceptions, which are found among foresters and engineers as well as lay persons, have not so far been borne out by experiment. Repeated short rotations of fast-growing species without replenishing soil nutrients do have a long-term negative effect on productivity, and eucalypts do compete for water resources. Alley-cropping experiments in agroforestry trials (planting between rows of trees), however, show the limiting factor for crop production to be light competition after three years in 2 x 4 spacing with no thinning or pruning, with these other concerns not emerging as significant factors in eucalypt systems.[1]

The Market for Eucalyptus

Charcoal and Fuelwood -- Although Eucalyptus camaldulensis is perceived to be a "miracle tree" of sorts because of its ability to grow in extremely poor conditions, the association of this species with charcoal production has not been made yet in Thailand. In general, however, Eucalyptus camaldulensis ranks well with other fast-growing species for charcoal production: it is reasonably dense; the stems grow straight, which allows for easy stacking in kilns; it has no thorns, unlike some fuelwood species; and it burns uniformly as charcoal.[2],[3] Perhaps the best energy use for eucalyptus is as fuelwood or charcoal, in small industries such as pottery manufacture.[4] According to one report, eucalyptus wood does not have a good reputation for cooking because it imparts a taste to grilled food, a common part of Thai cuisine.[5]

Pulp -- Eucalyptus camaldulensis is not a valuable species for pulp, being used primarily for production of cardboard, a relatively low-value product. At present, there is a primary processing facility being constructed near Bangkok that reportedly will purchase eucalyptus for pulp export. The Phoenix mill in Khon Kaen reportedly is buying some eucalypts for pulp, presumably to replace kapok, which is apparently no longer readily available near the plant. Additional mills for primary processing and subsequent export to paper plants in Japan and Taiwan are proposed. Some round wood is also being exported to these countries for paper production. Export regulations are beginning to be relaxed and taxes reduced for some forest products, to stimulate private market development. Harvesting and transportation costs may preclude profitable sales of trees to mills that are far from the woodlot, and although future mills are being discussed, it is unlikely that the prices for fiber for cardboard production will increase dramatically.

Poles and Lumber -- The market for construction poles in many areas of Thailand is currently glutted by an overabundance of Casuarina junghuhniana. This species was promoted in similar fashion to Eucalyptus in the past, essentially as a cash crop to replace rice during a period of low prices for rice. Although Thailand is the world's largest exporter of rice, agroforestry systems have been re-adopted to diversify agricultural products to promote economic stablity and ensure food supply for the farmer. It should be noted that Casuarina species grow extremely well in sandy soils and fix atmospheric nitrogen, which enhances chemical properties of poor soils. Seed selection programs for Casuarina have been quite good, producing high-quality, uniform stands throughout the central region and providing many applications for rehabilitation of unproductive sites throughout the country. The density of Casuarina wood makes it an excellent species for charcoal production as well as for poles, including pilings, scaffolding and telephone poles. There is very little market development for Casuarina, however, and many farmers who adopted RFD programs for planting these trees reportedly feel they are "stuck" with the trees. Cement poles are often less expensive than wood, they are stronger and do not rot.

Fiberboard -- Perhaps the best industrial use of eucalyptus is for fiberboard. Other species of eucalypts such as E. degulpta are better for plywood and fiber board, but do not grow as well under water stress. Quality of wood is not a major consideration in fiberboard production. Glue and pressure create structural strength in fiberboard and therefore any species that binds well with glues is satisfactory. Eucalyptus is easy to chip, and it is not so dense as to make fiberboard excessively heavy. Fiberboard is not in high demand at present, but with a decrease in availablity of timber species, the price of finished lumber is increasing dramatically, and fiberboard could serve as a good substitute. E. camaldulensis does not make particularly good furniture or other saw-timber products, because the grain is twisted; this makes it hard to work with and causes considerable change in shape and size as the wood dries. This species, therefore does not have as high a value for these uses as bamboo, rattan, or other species of tropical hardwoods.

Management of Plantations

Currently, the existing stands of eucalyptus have been cultivated for a short period and left to grow, essentially unmanaged. Rotation periods for fuelwood are much shorter than for sawlogs. With eucalyptus the rotation period ranges from four to eight years, depending on the end product and the site conditions. Concurrent use of the land for intercropping determines the spacing of rows in a tree plantation. The RFD and other organizations have done much research on these variables and the results of their experience should be conveyed to the village level.

The villagers of Thailand are industrious and innovative and, like most farmers in developing countries, have a good practical knowledge of agriculture that is the result of generations of experience. The complex home garden, rice-paddy management, aquaculture, and agroforestry systems are examples of common practices in Thailand that have developed from long experience. Forest management, on the other hand, with the exception of

fruit trees, has traditionally meant either resource extraction (similar to mining) or conservation through enforcement. Thai villagers, therefore, cannot be expected to have the same practical knowledge of tree-plantation management techniques, particularly with exotic species, as they have of agricultural systems - thus the need for the RFD and other concerned organizations to translate the results of their research and experience to the village level.

Although management of any forest stand, whether natural or of human origin with exotic species, requires knowledge of site-specific conditions and a socioeconomic analysis of local attitudes and market conditions, a few generalizations can be made on the basis of experience gained from the village-woodlot activity of the USAID/NEA project.

- Seed selection is a prime prerequisite to successful implementation of any plantation program. The stands established under the project show wide variation in form and vigor, which indicates that the seed-screening process should be improved. Four seed sources - Petford Australia, and seed orchards in Si Sa Ket, Surin, and Chiang Mai - were used by the RFD. The RFD should consider seeking other sources to ensure selection from ecotypes adapted to the stressed environmental conditions and site characteristics that exist where these woodlots are established. This is a necessary precondition to survival, vigor, and uniform growth.

  This precondition might well be met by using the stands established under the project, since they are themselves good sources of seed. To insure that good stock is obtained, high-quality, second-generation progeny should be isolated to prevent breeding with poor stock, and clones, mostly cuttings, should be obtained from the best trees. Nurseries with seed stock appropriate for each distinct set of environmental conditions could then be established in the regions that have those conditions.

  In addition to seed selection and vegetative propagation efforts, removing poor stems from existing woodlots will help produce more productive stands. This will reduce competition for light, soil nutrients, and water with the other trees and other crops in the understory; it will provide a continuous supply of wood for fuel or other use; and it will establish an uneven-aged management system that avoids the need to harvest all the trees in a woodlot at the same time. This basic management system must be understood by the villagers involved in woodlot-development projects.

  In the absence of pruning or thinning, intercropping is likely to be productive for only two years in stands with 2 x 4 spacing. The third and perhaps the fourth years will often be good for sowing grasses or legumes (e.g., Guinea grass, signal grass, or Hamata). Where it is desirable, taro, pineapple, sweet potato or other shade-tolerant crops can be grown under the trees. After four years, thinning the stand to remove poles and fuelwood will open the canopy to release the growing stock of trees and all for more ground-crop

production. Experience has shown that stands with intercropping grow better than those without, as a result of cultivation, which improves the physical characteristics of the soil to permit increased aeration and water availability.

- In terms of biomass production for fuelwood, close spacing (1 m x 2 m or 2 x 2) with a four- to five-year rotation period is best. For intercropping systems, spacings as much as 2 m x 8 m are preferred.

- Experiments have shown that coppice production of eucalyptus in the second rotation produces approximately three times the volume of wood produced in the first rotation, when the best three shoots are selected. Acacia, Peltophorum, and Leucaena produce similar volume ratios in the second rotation, but in these cases, five stems should be selected. In the third rotation, yields are only about half of the first rotation for all of these species; therefore only two rotations should be expected from one planting.[14]

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ANNEX 5

ORGANIZATIONS AND INDIVIDUALS VISITED AND INTERVIEWED

In gathering material for this evaluation, the members of the team visited numerous project implementation sites, government agencies, and private manufacturing facilities; held discussions with university project participants, government officers, and village officials; and interviewed private entrepreneurs, village residents, and members of village cooperatives. This annex presents a tabular summary of the people involved. [Full names and titles are given, where known. In some cases, only one name was known to the team.]

Abbreviations used:

CMU	Chiang Mai University
CUSRI	Chulalongkorn University Social Research Institute
FAO	Food and Agriculture Organization
ISTPRA	Institute of Science and Technology for Promotion of Rural Areas (Srinakharinwirot University)
KMITT	King Mongkut's Institute of Technology Thonburi
MET	Meteorological Department
NEA	National Energy Administration
NEIC	National Energy Information Center
PTC	Phanomprai Trading Corporation
REC	Regional Energy Center
RFD	Royal Forest Department
SNU	Srinakharinwirot University
TISTR	Thailand Institute of Scientific and Technological Research

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